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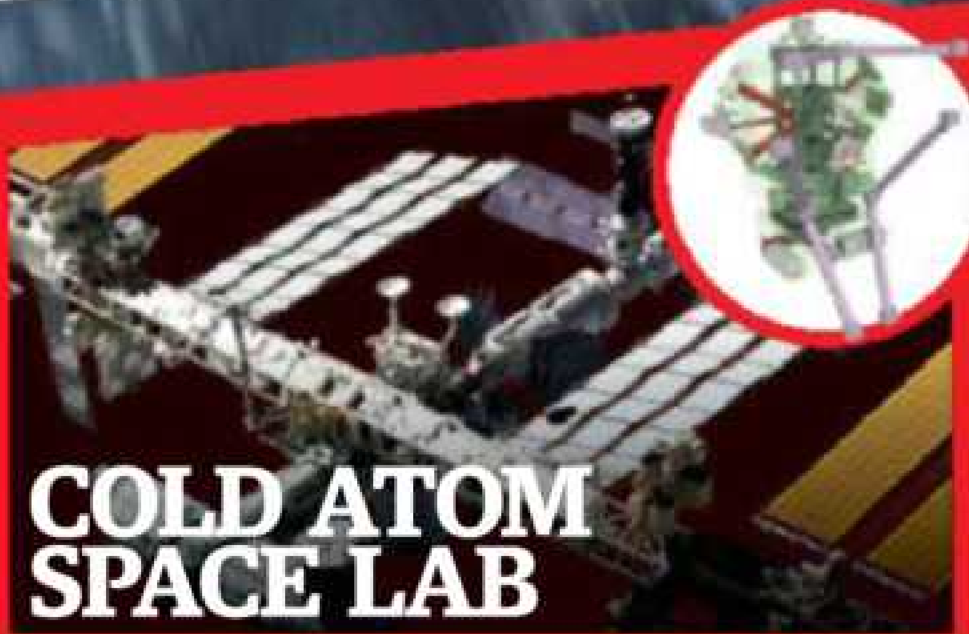

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Discover the wonders of the universe

What can we compare the Rosetta mission to? As far as publicity is concerned, it's at least as big as the hype of the months that led up to the arrival of the Mars Science Laboratory mission, which landed on the Red Planet in August 2012.

Maybe the interest this generated was because of the nature of the Curiosity rover's life-seeking mission, plus the fact that Mars has held public fascination for over a century now. And not to detract from MSL, it has proved a fascinating and worthwhile endeavour so far. But the European Space Agency's mission is completely unprecedented: we've never put a spacecraft in orbit around a comet, the incongruously named 67P/Churyumov-Gerasimenko that is blazing through our Solar System at a speed of up to 135,000 kilometres per hour (84,000 miles per hour). We've certainly never landed on an object like this before either, although NASA's Deep Impact mission did shoot a copper-based slug of metal into comet Tempel 1, back in 2005.

With the landing site chosen and date for the launch of the Philae lander set for 12 November, Rosetta is more comparable with long-past space pioneers, the likes of the Huygens probe and Voyager missions. While its immediate goals – to see what comets are made of and how they form – don't sound as cool as knowing whether there could have been life on Mars, or what the surface of Saturn's moon, Titan, looks like, we think that Rosetta's prime objective to understand the origin and evolution of the Solar System, could be the biggest space breakthrough in years.

Ben Biggs
Editor

Crew roster

David Crookes

■ Dave penned our cover feature and will be holding his breath until Philae lands on the comet in November.

Gemma Lavender

■ The sky's the limit in our beginners' guide to astronomy – find it on page 68 of Stargazer.

Jonny O'Callaghan

■ Jonny got greedy when deciding which Neptune explorer to focus his feature on.

Laura Mears

■ There's a lot to talk about on the subject of a 3 million-light-year-wide galaxy, so Laura found.

> "We didn't have any communication with it for two-and-a-half years"
>
> **Ritchie Kay, Rosetta spacecraft operations engineer**

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Biggest galaxy in space

> “The lander is the cherry on top... it lets us dig into that primordial material”
>
> **Matt Taylor, project scientist for the Rosetta mission**

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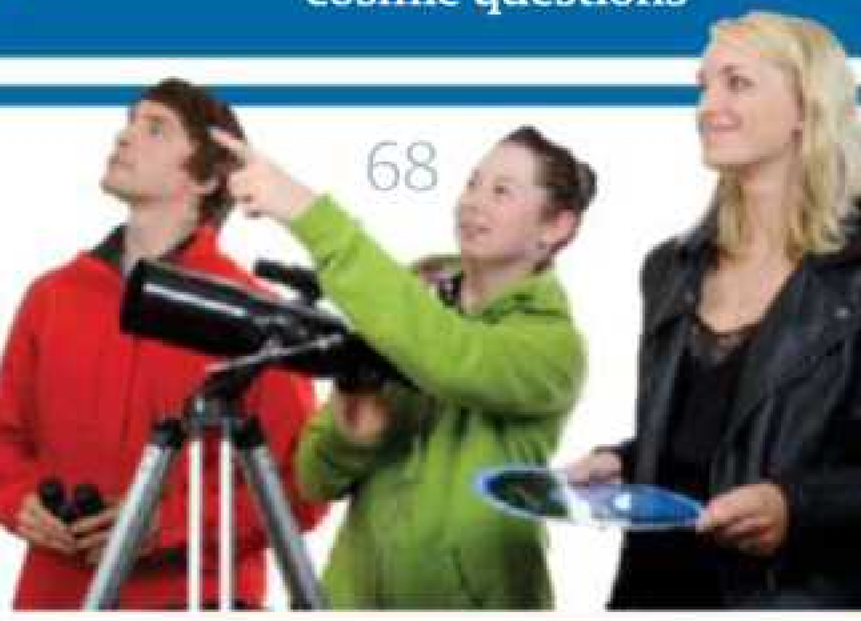
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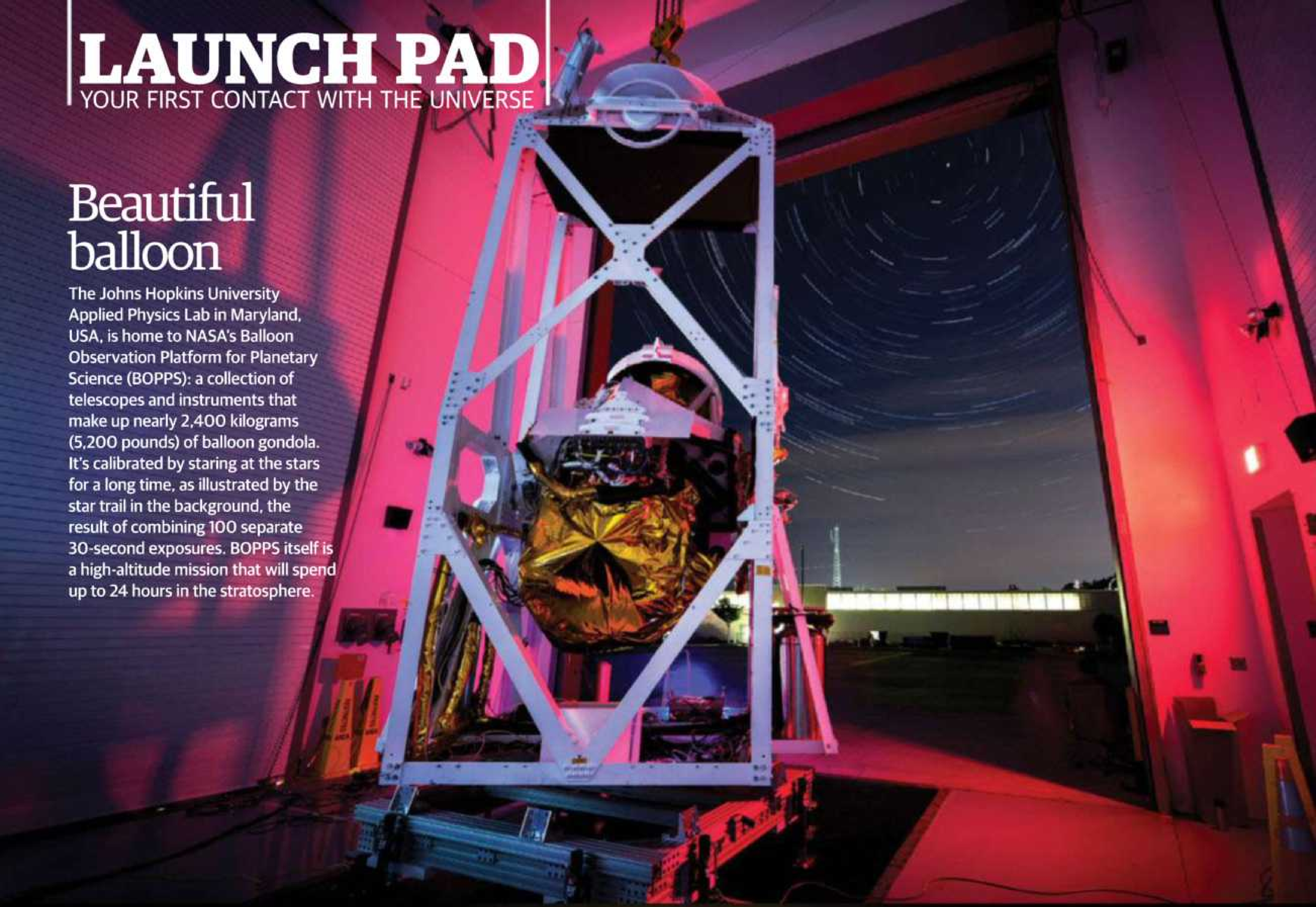
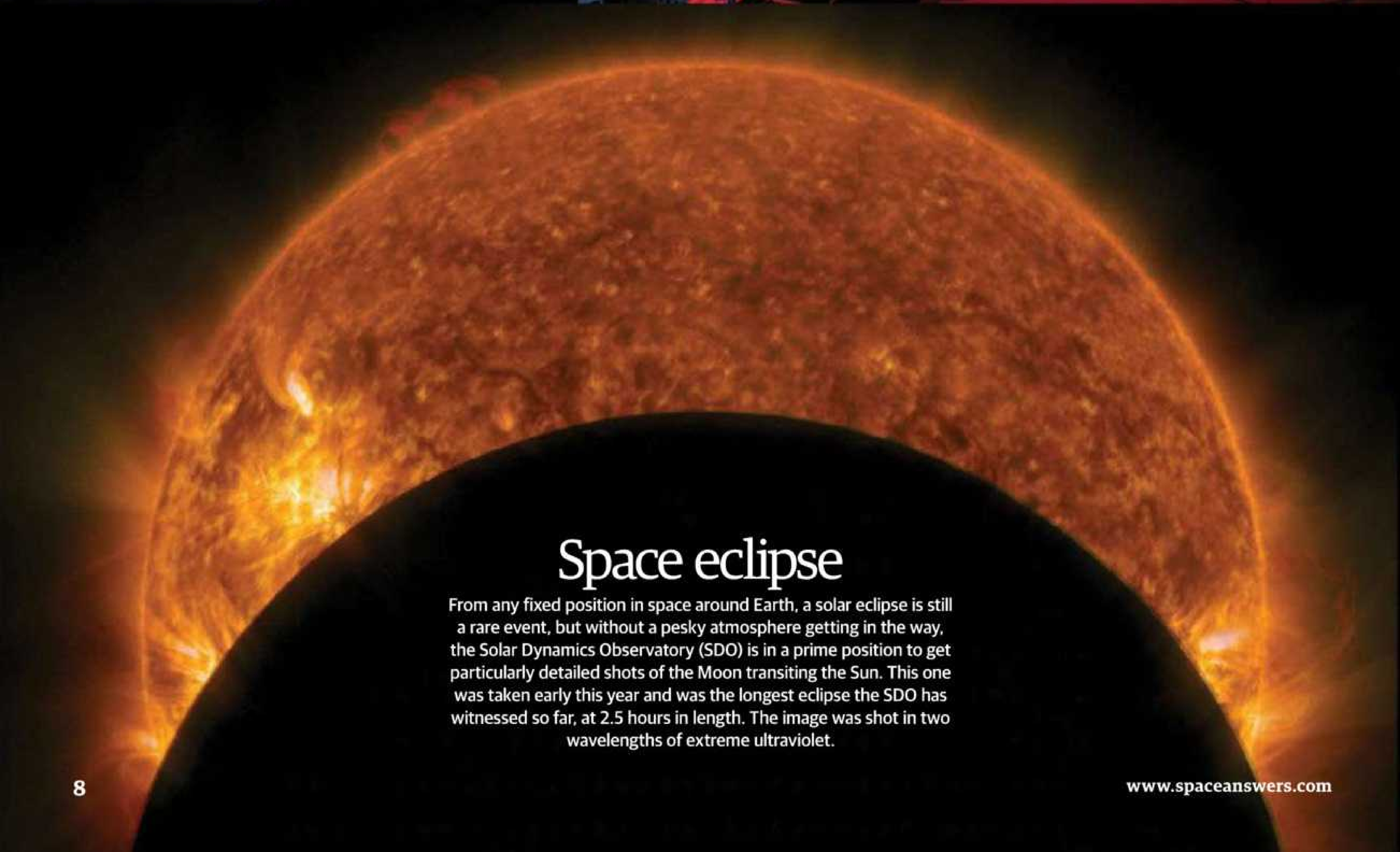
On a limb

The International Space Station's Mobile Servicing System is best known for its main component, the Canadarm 2. This 17.6-metre (57.7-foot) motorised limb can handle huge payloads of up to 116,000 kilograms (256,000 pounds) and was used to help dock the Space Shuttle. It isn't fixed in one place and can move around the ISS by flipping end over end to reach another module. Astronaut Stephen K Robinson can be seen in this image (taken in 2005) anchored to the Canadarm 2's foot restraint.



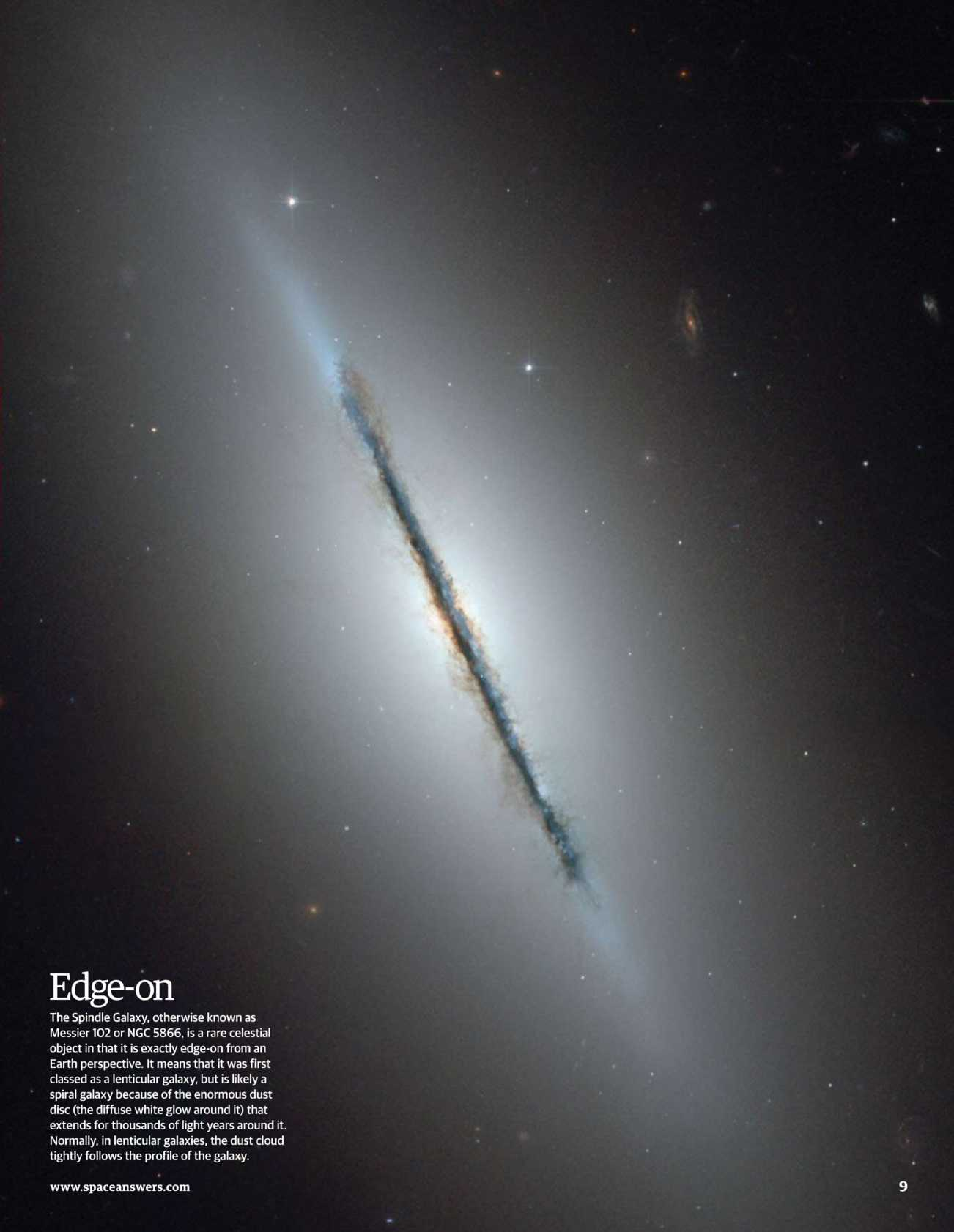
Beautiful balloon

The Johns Hopkins University Applied Physics Lab in Maryland, USA, is home to NASA's Balloon Observation Platform for Planetary Science (BOPPS): a collection of telescopes and instruments that make up nearly 2,400 kilograms (5,200 pounds) of balloon gondola. It's calibrated by staring at the stars for a long time, as illustrated by the star trail in the background, the result of combining 100 separate 30-second exposures. BOPPS itself is a high-altitude mission that will spend up to 24 hours in the stratosphere.



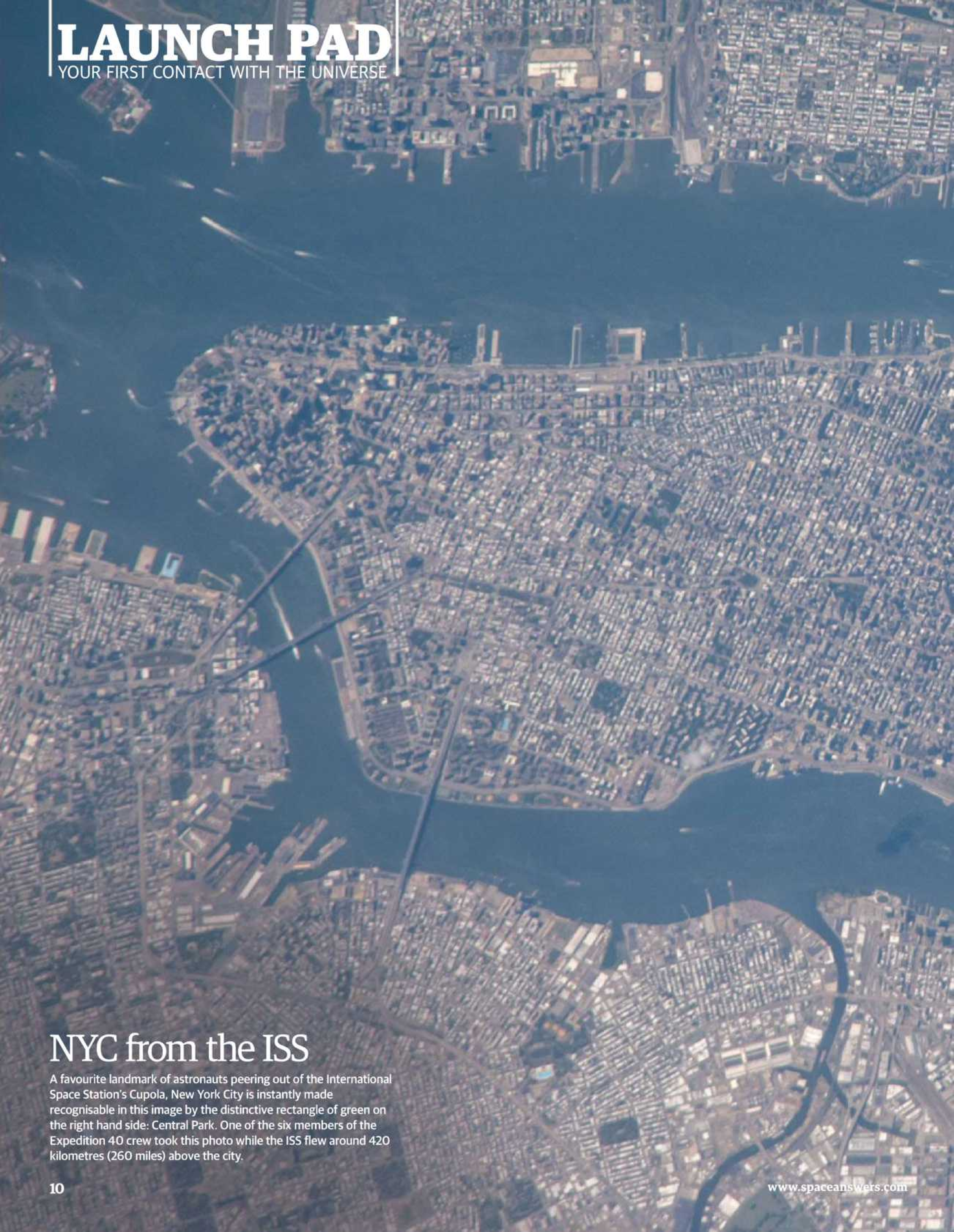
Space eclipse

From any fixed position in space around Earth, a solar eclipse is still a rare event, but without a pesky atmosphere getting in the way, the Solar Dynamics Observatory (SDO) is in a prime position to get particularly detailed shots of the Moon transiting the Sun. This one was taken early this year and was the longest eclipse the SDO has witnessed so far, at 2.5 hours in length. The image was shot in two wavelengths of extreme ultraviolet.



Edge-on

The Spindle Galaxy, otherwise known as Messier 102 or NGC 5866, is a rare celestial object in that it is exactly edge-on from an Earth perspective. It means that it was first classed as a lenticular galaxy, but is likely a spiral galaxy because of the enormous dust disc (the diffuse white glow around it) that extends for thousands of light years around it. Normally, in lenticular galaxies, the dust cloud tightly follows the profile of the galaxy.



NYC from the ISS

A favourite landmark of astronauts peering out of the International Space Station's Cupola, New York City is instantly made recognisable in this image by the distinctive rectangle of green on the right hand side: Central Park. One of the six members of the Expedition 40 crew took this photo while the ISS flew around 420 kilometres (260 miles) above the city.

© NASA, ESA

MAVEN makes it to Mars

Perfect orbital insertion burn nudges the probe into Mars's orbit, ready to return data about the Red Planet after a ten-month trip through the Solar System

There was relief at the Lockheed Martin Mission Support Area in Colorado as it was confirmed that NASA's Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft had perfectly executed the burn that took it into the orbit of Mars, from which it has already sent back early images.

The project, which was conceived 11 years ago, reached its critical phase on 21 September when the spacecraft had to make a perfect fuel burn so it could slow down enough to be captured by its target planet.

Members of the mission broke out into applause when it was confirmed that the burn had been successful and MAVEN could begin its historic task of mapping the upper atmosphere of Mars.

"This was a very big day for MAVEN," said David Mitchell, who is the project manager of the mission. "We're very excited to join the constellation of spacecraft in orbit at Mars and on the surface of the Red Planet. Congratulations to the team for a job well done."

During its Earth-year long mission, MAVEN will 'deep-dip' five times to a height of 125 kilometres (77 miles) above the surface of Mars, where it will provide invaluable information about the point at which the upper and lower atmospheres of the planet come together.

"As the first orbiter dedicated to studying Mars's upper atmosphere," said NASA administrator Charles Bolden, "MAVEN will greatly improve our understanding of the history of the Martian atmosphere, how the climate has changed over time and how that has influenced the evolution of the surface and the potential habitability of the planet."

MAVEN has three major pieces of kit that will carry out analysis of Mars's atmosphere and report back to the team. The Remote Sensing Package is responsible for identifying what aspects of the upper atmosphere and the ionosphere are present in both, the Neutral Gas and Ion Mass Spectrometer is measuring the composition and isotopes of atomic particles and the Particles and Fields Package will look closely at the solar wind and ionosphere.

The first images returned were false-colour images that showed ultraviolet light as it was scattered by an extended cloud of hydrogen gas, a smaller cloud of atomic oxygen and the planet's surface. MAVEN is to continue monitoring these gas clouds in order to discover how much hydrogen and oxygen Mars is losing from its atmosphere. This data will help us to understand how much water the planet has lost since it first came into being.

MAVEN arrives at the Red Planet where it will study the Martian atmosphere for the first time

> "Members of the mission broke out into applause when it was confirmed that the burn had been successful and MAVEN could begin its historic task"

The clear skies over HAT-P-11b let three major telescopes confirm that were was water vapour coming from the exoplanet, sparking hopes that more could soon be found

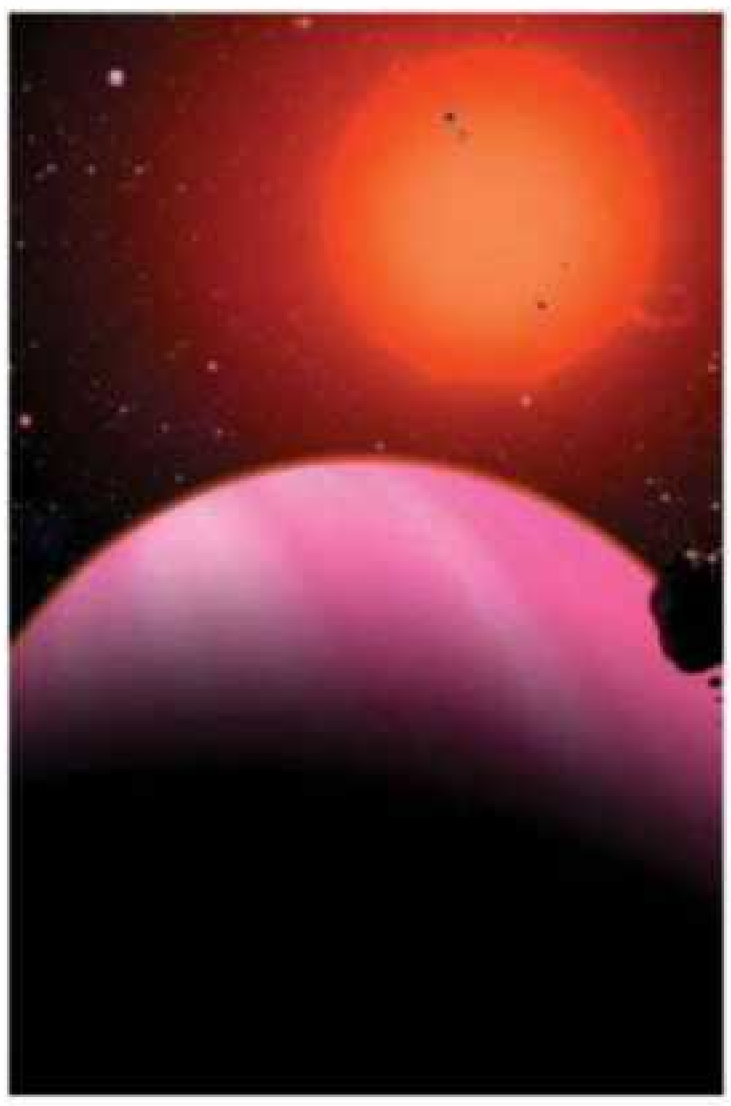
Clear skies ahead

Water vapour found on Neptune-sized planet 120 light years from Earth

Astronomers had a stroke of good fortune when clear skies meant they could detect water vapour on a planet outside our Solar System.

HAT-P-11b is an exoplanet around 120 light years away from us that orbits HAT-P-11, a star in the constellation of Cygnus. Telescopes Hubble, Kepler and Spitzer all worked together to detect and prove water vapour was rising from its surface.

The good fortune came with the cloudless skies that allowed Hubble to make the discovery that gives astronomers hope that there could be similar water-containing planets residing in the area.



The water vapour was detected by Hubble's Wide Field Camera 3

The assistant administrator of NASA's Science Mission Directorate John Grunsfeld said, "This discovery is a significant milepost on the road to eventually analysing the atmospheric composition of smaller, rocky planets more like Earth."

HAT-P-11b is around the size of Neptune, which is another cause for celebration as previously it was only much larger planets that were able to be seen and analysed, making this the smallest planet that scientists have been able to detect molecules on so far. Its composition is gaseous with a rocky core and it orbits its star once every five days.

The water vapour was detected using Hubble's Wide Field Camera 3, which watched HAT-P-11b as it crossed in front of its star. Having noticed water vapour molecules by using transmission spectroscopy, it had to collect data from Kepler and Spitzer to prove they weren't from starspots on HAT-P-11. Joint observations from the two telescopes showed that the starspots couldn't be giving off deceptive steam so Hubble's discovery was confirmed.

Scientists now hope to go on to discover many more water-containing planets, especially ones with a composition more like our Earth.

Heather Knutson, who is co-author of the study, said, "The work we are doing now is important for future studies of super-Earths and even smaller planets." ●

Dragon hooked up to the ISS having chased it through space for two days to deliver its cargo of supplies, mice and a 3D printer

Who ordered mice?

SpaceX's Dragon docked with the ISS on 23 September, having chased it down for two days.

It was tasked with delivering supplies for astronauts on board the space station, a 3D printer and a selection of mice that will be used in an experiment on muscle degradation.

After the Dragon caught up with the ISS, astronaut Alexander Gerst managed to grab it with a huge robotic arm to pull it in to safety and unload its cargo.

This docking is the fourth in a series of 12 missions that NASA has booked with the private aerospace company to deliver and take back a variety of essentials and equipment for experiments.

The 20 mice will be used to discover more about how and why astronauts lose muscle mass while in outer space and if there is any way to counteract this problem. The 3D printer will be used to print 3D objects for the first time in space, before returning with the Dragon for analysis on how much microgravity affects 3D printing.

There are also two ongoing missions onboard the craft, with oxidative stress-resistant fruit flies and space-grown lettuce due to return when it heads back to Earth in mid-October. ●

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Lemon-aid for space designers

ESA scientists have hit on a new way to keep their stainless steel pristine. The metal is usually cleaned with nitric acid, which is neither safe nor environmentally sound, so lemon juice has been put forward as an alternative.

What's the matter?

Scientists have detected a huge number of antimatter particles which could hint to the origin of dark matter. Using the Alpha Magnetic Spectrometer to search deep into space, researchers say they are a step closer to finding the elusive invisible matter.

Planets age stars

A study has suggested that some planets may have ageing effects on the stars they orbit. Researchers believe that the gravitational pull of planet WASP-18b has disrupted the magnetic field of its star WASP-18, reducing its X-ray emission and making it seem much older.

Curiosity drills deep

NASA's Curiosity Mars rover has drilled down into a Martian mountain to collect its first sample. The rover went 6.6 centimetres (2.6 inches) into the surface of the Red Planet to collect powdered rock for analysis by the rover's internal laboratory.

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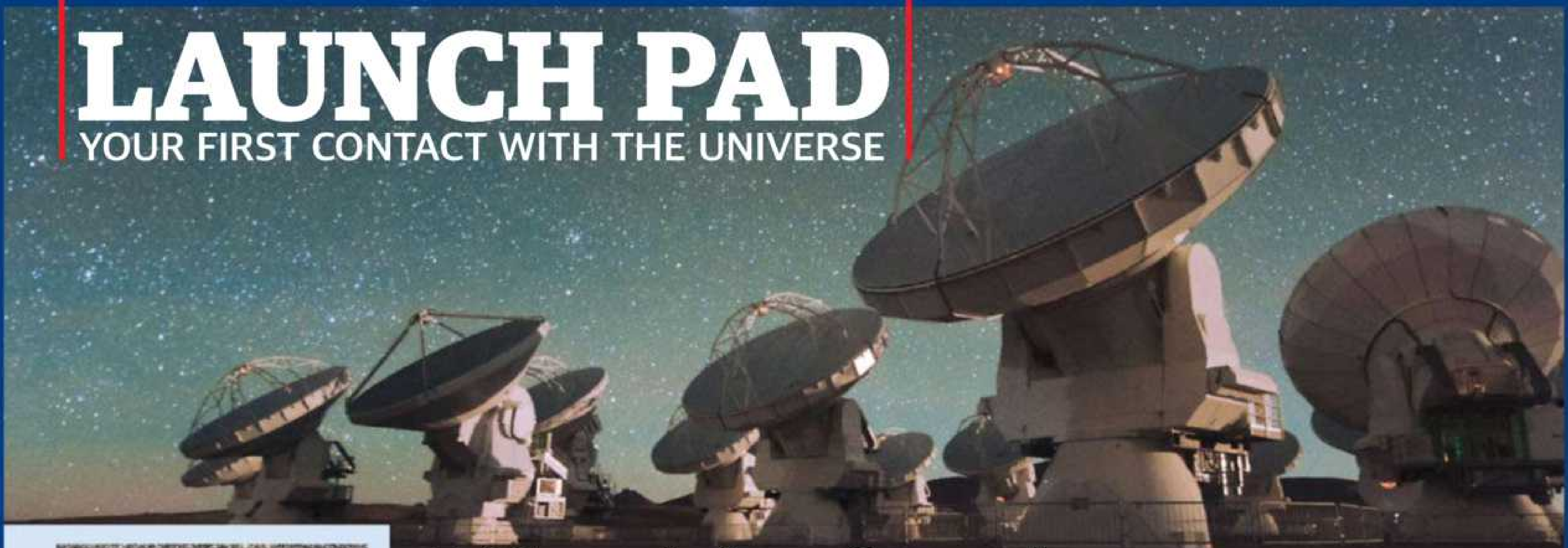

The ALMA telescopes that detected the isopropyl cyanide, which could give us more clues about the origins of life

Life origins found

Chemicals that form the basis of life have been discovered in our galaxy

Molecules have been detected near the centre of the Milky Way that are more complex than any discovered in space before.

The Atacama Large Millimeter/submillimeter Array (ALMA) in Chile has found isopropyl cyanide in the giant gas cloud Sagittarius B2. This amino acid is a key component of the building blocks of life. This represents an exciting step in discovering where life came from, as complex carbon structures such as these have never been found in space before.

The most interesting part of these structures is the branched carbon backbone that gives hope that we could find even more complex structures in the galaxy, learning more about how life came to exist in the universe.

The study was run by the Max Planck Institute for Radio Astronomy and they are set to look further into the heart of the Milky Way in order to try to discover more of these amino acids.

If more complex structures can be found in our galaxy and beyond, this makes it more likely that life has been able to occur in other parts of the universe.

The Sagittarius B2 cloud has proved to be a rich source of molecules already, housing vinyl alcohol and ethyl formate. ●

MOM calls home

India's first mission to Mars has reached its destination after entering orbit around the Red Planet

The Indian Mars Orbiter, before it set off on its history-making journey to the outer reaches of Mars's atmosphere

The Indian Mars Orbiter Mission (MOM) has followed in the tracks of NASA's MAVEN mission by manoeuvring itself into Mars's orbit, where it plans to stay for between six and ten months. During this time it will measure methane levels on the Red Planet.

As well as being a scientific triumph, the MOM mission is also a major step forward for the Indian Space Research Organisation (ISRO), as it has now become only the fourth nation group to reach the fourth planet from the Sun, following the USA, Europe and the former Soviet Union.

Having launched ten months ago, the £46- ($75-) million probe will primarily investigate what turned the once warm, wet planet into the dry dustbowl that we see today. It will also attempt to see if there is any residual methane on the planet, which could have been produced by a living thing.

Each orbit of the planet should take just under 73 hours and it will get as close as 422 kilometres (262 miles) away from the surface of the planet.

India's Prime Minister Narendra Modi made a speech congratulating the mission's members and tweeted, "History is created [and I] am glad to have witnessed it. Will never forget this day! Congrats to our scientists."

NASA was also in congratulatory mood with its administrator Charles Bolden saying, "It was an impressive engineering feat and we welcome India to the family of nations studying another facet of the Red Planet. We look forward to MOM adding to the knowledge the international community is gathering with the other spacecraft at Mars."

MOM's arrival at Mars takes the number of probes currently orbiting the planet up to five. Three belong to NASA, while Europe's representative is the Mars Express. ●

The supermassive black hole at the centre of M60-UCD1 makes up a huge part of the galaxy. Scientists believe the galaxy was once much larger than it is now, however

Supersized hole in galaxy

Astronomers got a supermassive surprise when they discovered a black hole with the mass of 21 million Suns in one of the smallest galaxies ever found.

The M60-UCD1 dwarf galaxy is 500 times smaller than the Milky Way yet it is home to a black hole that is more than five times the mass of the one at the centre of our own galaxy.

It is thought that it was once a large galaxy containing 10 billion stars, but got pulled apart when it passed close to another galaxy, the giant elliptical M60, which it now orbits. M60 itself has a whopping supermassive black hole at its core, weighing in at 4.5 solar masses.

The dwarf galaxy can be found 54 million light years from Earth, just 22,000 light years from M60's massive core. It's thought that this galaxy could ultimately end up as a snack for M60's insatiable black hole, although exactly when that will happen is unknown. ●

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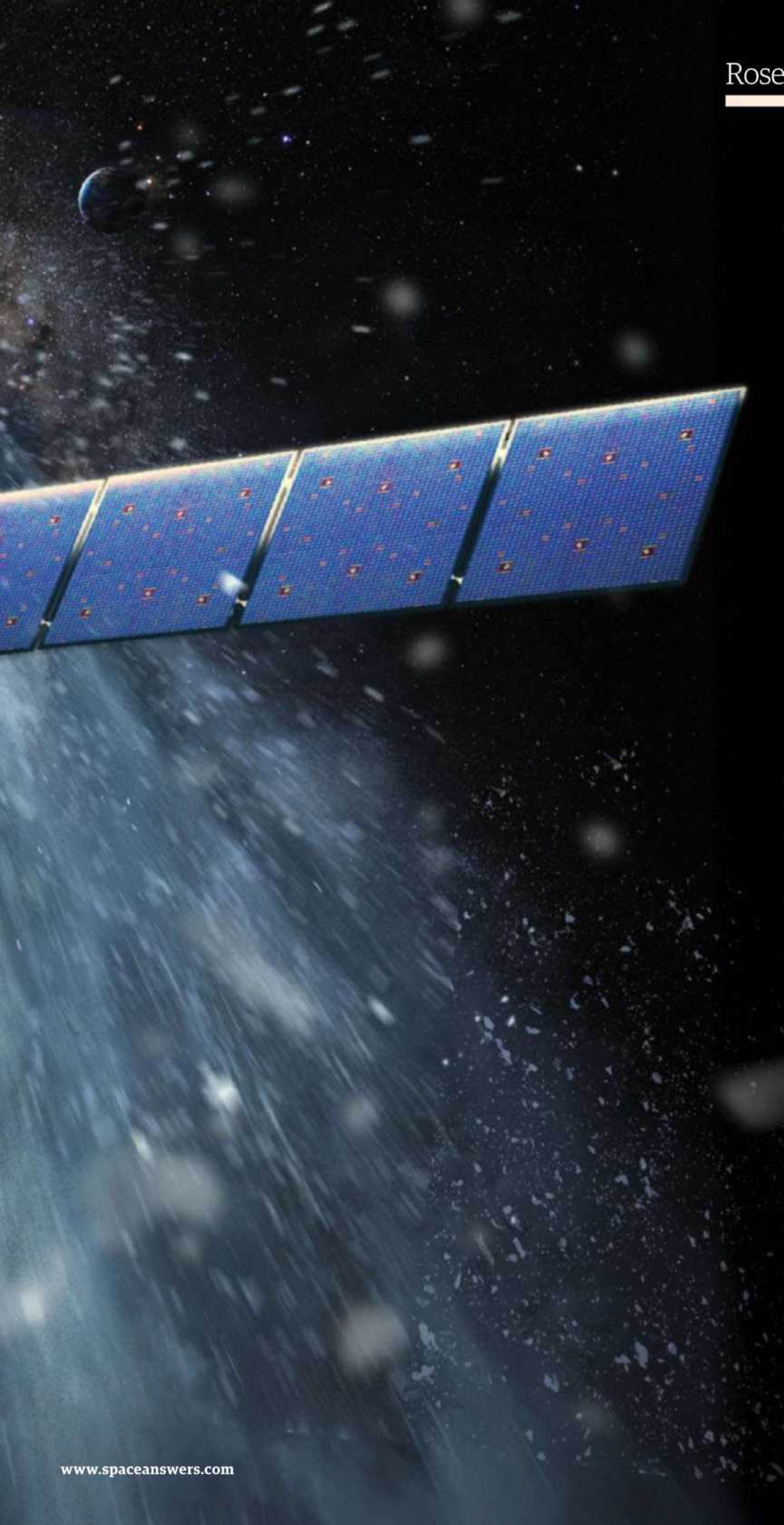
THE GREAT COMET CHASER

ROSETTA

For the first time in history, a space probe is orbiting around a comet in the hope of uncovering the secrets to life on Earth. As scientists plan to send a lander to its surface, **All About Space** looks at the mission so far

Written by David Crookes



Good things, it is believed, come to those who wait. For scientists at the European Space Agency and for space enthusiasts the world over this well-worn saying has proven to be very much true. It has been more than ten years since the Rosetta spacecraft was sent to meet comet 67P/Churyumov-Gerasimenko but now it seems patience is paying off.

Not too long ago, on 6 August 2014, Rosetta got within touching distance of the comet, prompting an almighty cheer from delighted scientists and engineers. Rosetta entered the comet's orbit and began to fly alongside it - an unprecedented move and an historical first. Previous missions to collect data and dust samples from comets have only involved fly-by missions, which have crossed the comet's path but have remained around 100 kilometres (62 miles) away.

Rosetta, however, has been incredibly ambitious in its approach. Right from the start, the idea was for the spacecraft to embark on a 6-billion-kilometre (3.7-billion-mile) comet-chasing journey and actually accompany one on its orbit past the Sun. In doing so, Rosetta's orbiter will get as close as ten kilometres (6.2 miles) from the comet but the plan in November is to get even closer. A robotic spacecraft will attempt to land on a comet's surface, another goal that has never been achieved before.

What we are seeing - and will continue to see as a result of this - is nothing short of spectacular. Anyone who has ever viewed a comet from the comfort of Earth will see the result of these small, icy bodies heating up when they pass close to the Sun. The effect that this has on the coma, or visible atmosphere of each comet, makes them appear as if they are shooting though the air like a ball of fire, often followed by a prominent gassy tail.

Although comet 67P/Churyumov-Gerasimenko (67P/C-G) is one of over 5,000 known comets (around a trillion are believed to exist in total), scientists have never truly been able to get to grips with one until now. The unmanned mission offers unprecedented access to a comet, enabling the collection of invaluable data about its composition and physical properties. Scientists say this will ensure that every penny of the £1 billion ($1.6 billion) cost of the project will be money well spent.

When you consider what a comet is, you soon understand why they're incredibly important for astronomers. Each and every comet is a primordial leftover from the early Solar System, dating back some 4.6 billion years. At that time, a dusty gas ball had collapsed into what we know today as the Sun and there was a rotating circumstellar disk of dense gas surrounding it. This was called the protoplanetary disk. When that was formed, bits of debris were cast aside, with the freezing temperature locking much primordial material into them. So, studying a comet is effectively just like looking through a window into the history of our galaxy.

ESA scientists identified the need to explore comets in greater detail in the Nineties, opening a new frontier for space exploration. As with all such missions, it took a great deal of time to organise properly, so Rosetta was not launched until March 2004. By that point scientists had identified 67P/C-G as a suitable target. The comet had been observed

Churyumov and Svetlana Ivanovna Gerasimenko and, with it set to be at its closest point to the Sun on 13 August 2015, it was in a perfect position to be met by Rosetta as it embarked on its decade-long flight.

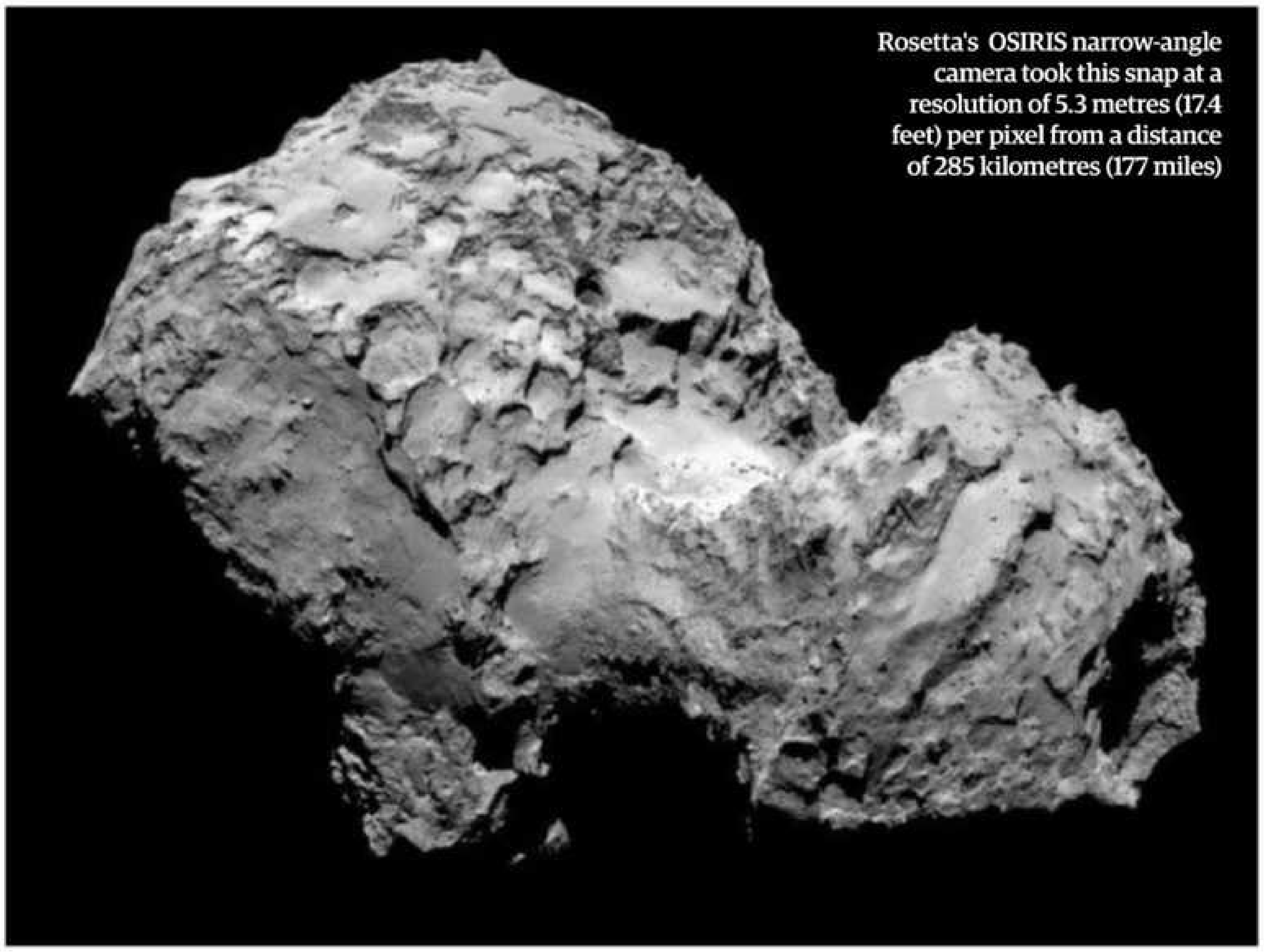
After lifting off from Earth, from French Guiana, Rosetta used the gravitational pull of the Solar System's planets to help accelerate it forward. It flew by Earth three times in 2005, 2007 and 2009, by Mars in 2007 and by two asteroids in 2008 and 2010. In the process, it orbited the Sun five times. When it reached a point furthest away from the Sun, the craft was put into a 31-month hibernation. If it hadn't been put into an electronic sleep, its solar panels would have been unable to gather enough energy for its comet-chasing journey. In conserving its power, it was able to continue its mission upon waking.

By the time the spacecraft was stirred into action in January 2014, the comet was midway between the orbits of Mars and Jupiter and Rosetta was suddenly able to begin taking photographs of 67P/C-G, much to the relief of the mission scientists assembled on the ground. But if there was elation that Rosetta had woken up on cue earlier this year, and was able to start sending some data back to Earth, it was nothing compared with the sheer relief felt by scientists on 6 August 2014.

On that day ten years, five months and four days of waiting came to a satisfying end. The Rosetta spacecraft embarked upon the final approach, fired its thrusters for six and a half minutes and commenced a strange triangular orbit around the comet it had caught up with at long last. Even though the mission had gone like clockwork from the moment Rosetta was launched, the vast distance between the comet and scientists on the ground - some 400 million kilometres (250 million miles) - meant news of the success did not reach them for 22 agonising minutes. It could have been a heart-stopping moment for scientists but it thankfully went without a hitch.

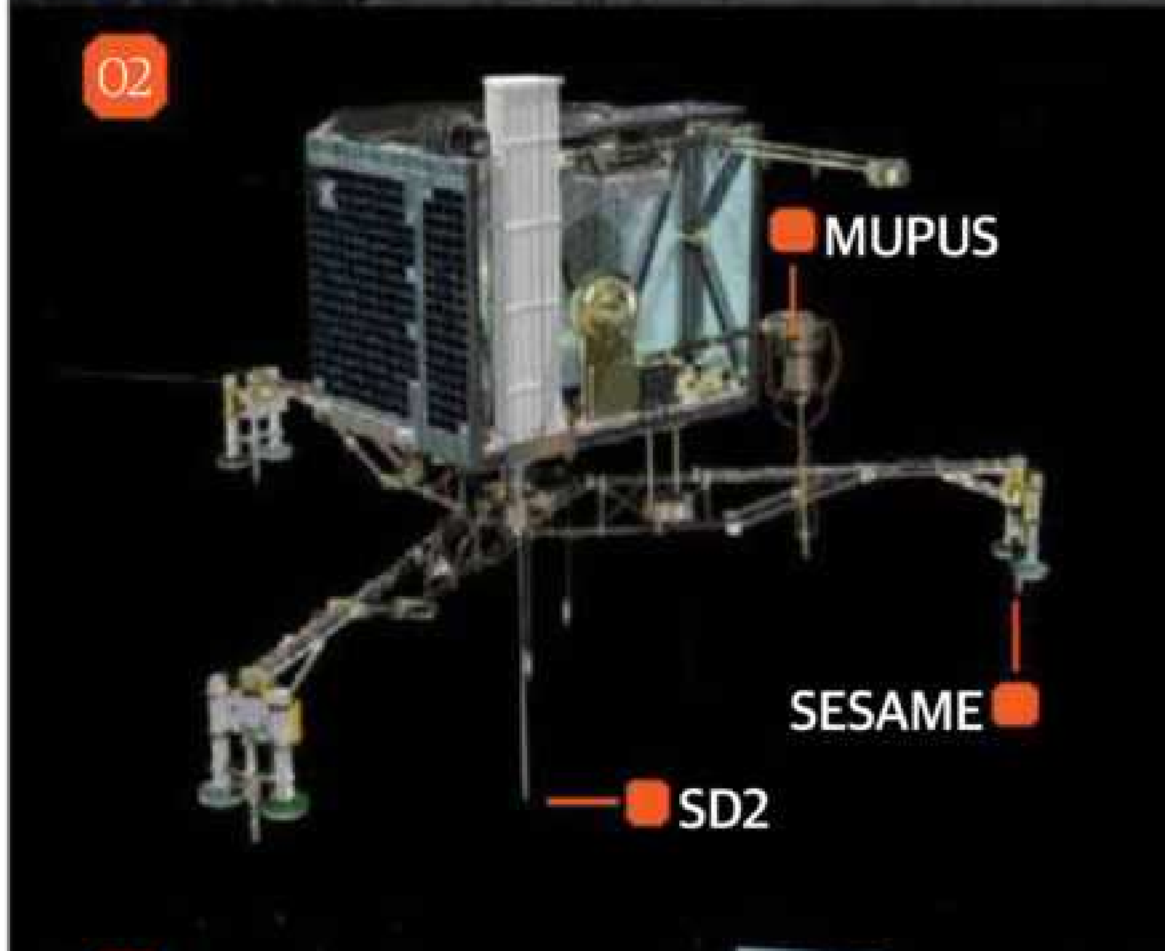
This time delay will be typical of the mission, meaning every move has to be made in advance in the hope that it will be carried out correctly a little while later. But for those at ESA's centre in Darmstadt, Germany, this tiny delay matters little. With the long wait at an end, mere minutes mean nothing and they are more than ready to unravel the many secrets of what astronomers have long called a mysterious mini ice world. Or, if you are Rosetta's project scientist Matt Taylor, a "flying potato."

"A number of us have described it in that way," Taylor laughs, pointing out that the general


Rosetta's OSIRIS narrow-angle camera took this snap at a resolution of 5.3 metres (17.4 feet) per pixel from a distance of 285 kilometres (177 miles)

01

02



03

History of the Rosetta mission

January 2003

Rosetta scientists were all set to fire up the spacecraft to meet the comet 46P/Wirtanen but an issue with the launcher caused a delay. This forced them to look for another comet.

March 2004

With 67P/C-G identified as an alternative, Rosetta was launched in French Guiana on 2 March 2004. 67P's similarity to 46P meant few changes were made.

June 2011

Having performed fly-bys of Earth and Mars, Rosetta, powered via solar panels, was at a point furthest away from the Sun, so had to be put into hibernation to save energy.

January 2014

Rosetta was awoken from its deep-space sleep on 20 January 2014 much to the delight of scientists. It was then on its last leg on the journey.

Landing on a comet

Scientists hope to place the lander on the comet's surface in November

1. Picking a site

From the moment Rosetta entered 67P/C-G's orbit and began to send back images of the surface, scientists started to look for a suitable site on which to land a probe. It will be the first time a human-made object has ever docked on a comet. A small robotic lander called Philae will separate from the Rosetta spacecraft on 12 November.

2. Instrumentation

The Philae lander contains ten instruments. They include plasma instrumentation, cameras and mass spectrometers that will look at the molecular makeup of the environment. There are three SESAMEs (Surface Electric Sounding and Acoustic Monitoring Equipments) to probe the mechanical and electrical parameters of the comet. There are two Comet Nucleus Infrared and Visible Analysers (CIVA) to take panoramic images of the comet's surface, as well as a sampling, drilling and distribution subsystem (SD2). Two Multi-Purpose Sensors for Surfacer and Subsurface Science (MUPUS) are also attached. There is also an Alpha Proton X-ray Spectrometer (APXS), a CONSERT (Comet Nucleus Sounding Experiment by Radiowave Transmission) that will study the internal structure of the comet nucleus. A PTOLEMY will look at the geochemistry of hydrogen, carbon, nitrogen and oxygen. There is also a Rosetta Lander Imaging System (ROLIS), a COSAC (Cometary Sampling and Composition) instrument to detect complex organic molecules and a Rosetta Lander Magnetometer and Plasma Monitor (ROMAP) to study the comet's magnetic field.

3. The descent

Philae will descend from a height of around one kilometre (0.6 miles). Since the comet's gravity is tens of millionths of that experienced on the surface of Earth, the lander will be deployed at a very low speed, no more than around 50 centimetres (20 inches) per second.

4. Surveying the surface

Once Philae lands, it will use ice screws on its feet to secure itself, then fire two harpoons into the surface to make sure it doesn't bounce off. The harpoons have cables attached, which will tell scientists more about the surface material.

Measurements will also be taken between the lander's feet to examine the conductivity of the surface. A hammering mechanism will look at the comet surface's sonic properties. By physically sampling the material the nucleus surface is made from, scientists will gradually be able to get a good idea of the textural make-up of the comet.

04

> "The lander will be deployed at a very low speed"

May 2014

Rosetta began a series of orbital correction manoeuvres, with some of the thrusts lasting several hours. The speed was being gradually reduced to around 1m/s (3.3ft/s), ready for orbit insertion.

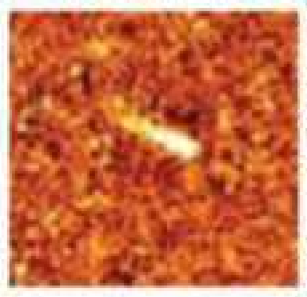
August 2014

On 6 August 2014, Rosetta entered the comet's orbit and began its triangular path around it, keeping pace with the comet as it hurtled towards the Sun.

November 2014

On 12 November, the lander will be released, touching down on the comet's surface before sending information back to the orbiter, which will then relay it back to Earth.

August 2015



Having reached the point in its orbit when it's closest to the Sun (the perihelion), the comet will have displayed many changes. Scientists will have observed them close up.

December 2015

The mission will come to an end, although there is much talk about extending it into 2016 or even 2017 to see how the comet re-energises itself.

consensus is that 67P/C-G looks like a rubber duck. "But then all of the observations scientists have made up to the point of Rosetta meeting 67P/C-G have only been preliminary. We've had estimates of what the comet looks like and what its rotation rate was, but close-up space-based observations are giving us much more of an idea. Being up close to a comet for the very first time is truly exciting, sexy even, and we are in a position to learn so much more."

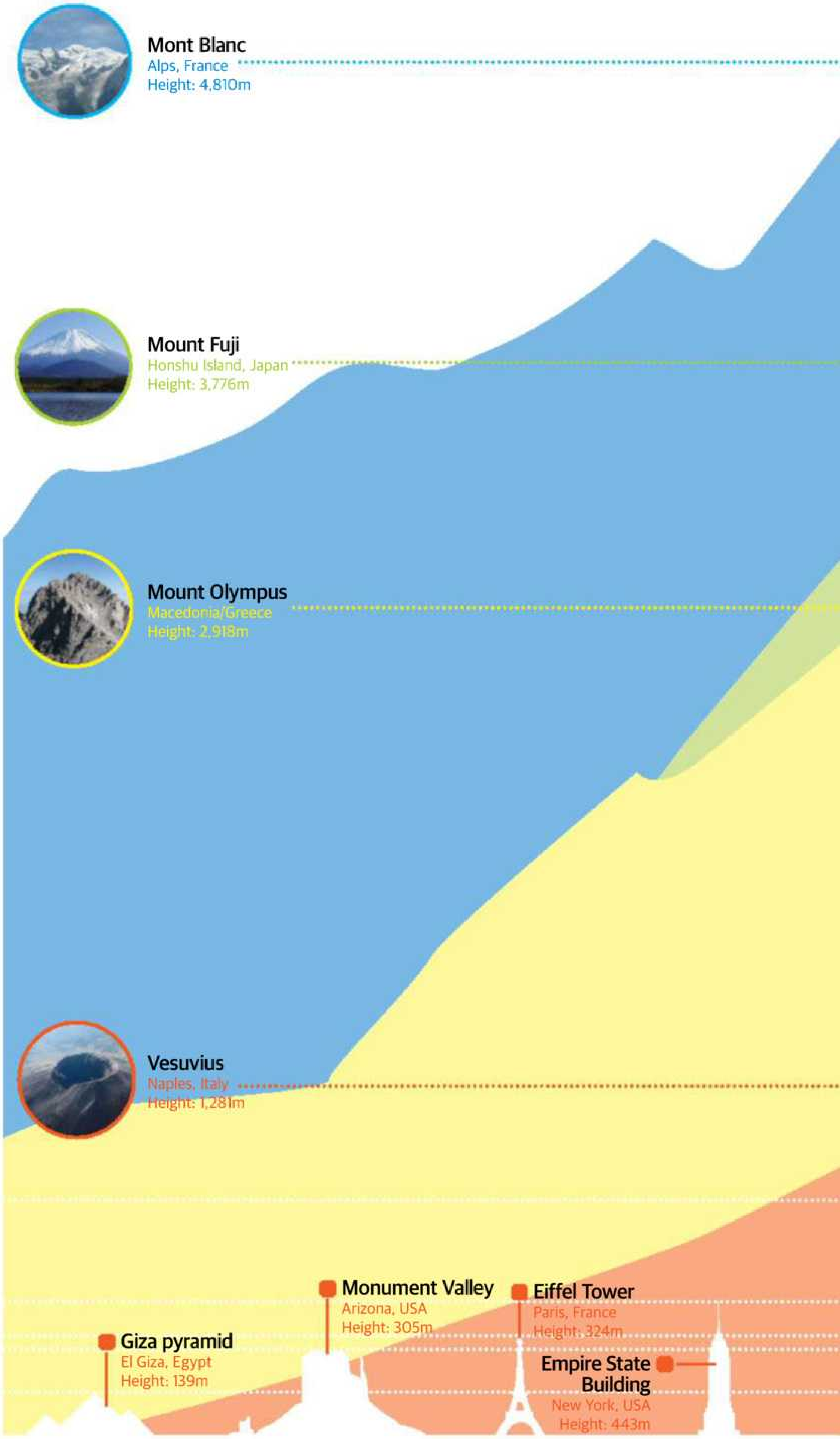
Right now, as you read this, Rosetta - named after the Rosetta Stone which has provided the key for the modern understanding of Egyptian hieroglyphs - is continuing to escort the comet as it heads towards the Sun at 55,000 kilometres (34,000 miles) per hour. It will keep pace with 67P/C-G for more than a year, travelling at a relative speed that falls within one metre (3.3 feet) per second. In order to achieve such a speed, Rosetta had to slow down from the 800 metres (2,625 feet) per second it had been travelling when it came out of hibernation. Scientists performed rendezvous manoeuvres to subsequently put the brakes on.

"It means we can ride along," says Taylor of the incredible feat currently being performed. "We're escorting the comet rather than flying past it and then coming back again. We'll stay alongside it at walking pace which, scientifically and also from an operational perspective, makes things a bit less risky." He refers to the Giotto spacecraft, which flew by and studied Halley's Comet. "That spacecraft suffered some significant impact damage from Halley's Comet and broke one of the instruments," continues Taylor. "It was travelling at a kilometres-per-second relative speed which, in a dusty and lumpy environment, is quite dangerous. If you're travelling at a metre-per-second it's not as big a problem."

With all the technical issues addressed and with Rosetta happily in orbit around the comet, scientists can now test a whole host of theories, which they hope will give them a greater understanding, not just about comets but the Solar System as a whole. Aboard Rosetta are 21 instruments, ranging from spectrometers to imaging systems, and these will be used to map the surface of the comet's nucleus and test its atmosphere. Each week there will be a series of thruster burns to keep the spacecraft in orbit around the comet. These vital manoeuvres will enable scientists to continue working out what comets contain, how they evolve and how they work.

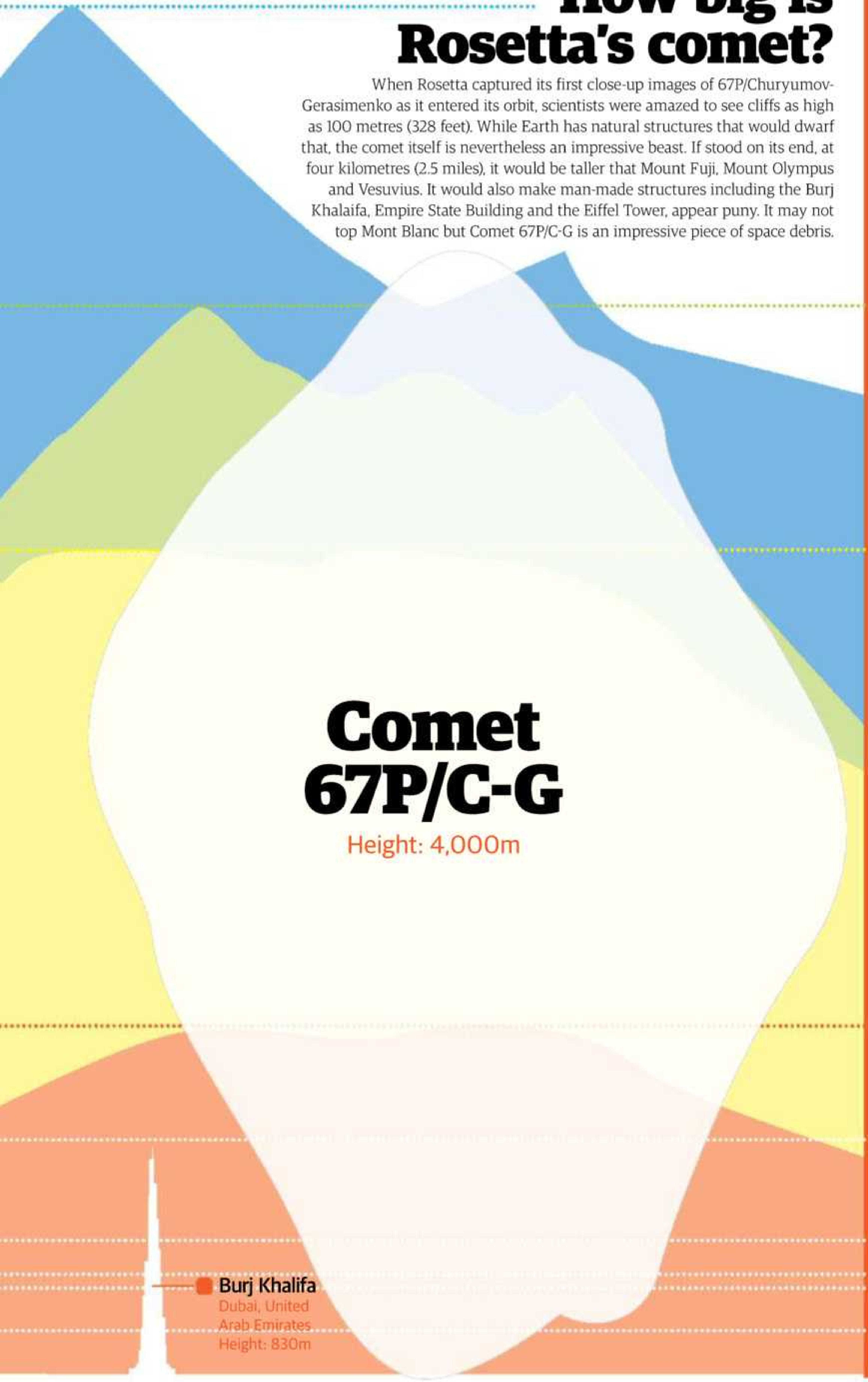
Experts will also be able to gain better answers to one of the most burning questions about comets: did they deliver water and carbon to Earth, helping to spark life on our planet? There has been much debate over where water has come from and what organic molecules exist within comets. By watching 67P/C-G as it transforms from its current inactive, cold state to one that is active and able to shed hundreds of kilos of dust and glass as it gets closer to the Sun, Rosetta is in a great position to answer this query.

"Previous observations from a number of other missions have shown that different classes of comet have different types of water," Taylor says. "So if you look at the isotopic ratios of water and compare them with other bodies in the Solar System, they give you a track back and a benchmark as to where they may all have come from." He says 67P/C-G is believed to have an isotopic ratio similar to Earth, which could



How big is Rosetta's comet?

When Rosetta captured its first close-up images of 67P/Churyumov-Gerasimenko as it entered its orbit, scientists were amazed to see cliffs as high as 100 metres (328 feet). While Earth has natural structures that would dwarf that, the comet itself is nevertheless an impressive beast. If stood on its end, at four kilometres (2.5 miles), it would be taller that Mount Fuji, Mount Olympus and Vesuvius. It would also make man-made structures including the Burj Khalaifa, Empire State Building and the Eiffel Tower, appear puny. It may not top Mont Blanc but Comet 67P/C-G is an impressive piece of space debris.



"The day was very tense for everybody"

Ritchie Kay, Rosetta spacecraft operations engineer

Although created to further scientific interests, the mission has also been a major feat of engineering. Ritchie Kay provides support for mission planning and operations.

Were there any problems getting to 67P/C-G?
The biggest issue has been keeping the teams together and the knowledge in place. There are lots of different instrument teams involved, spread across different European and American institutions. With a mission that has taken so long to get to this point, there is always the challenge of trying to keep everything together.

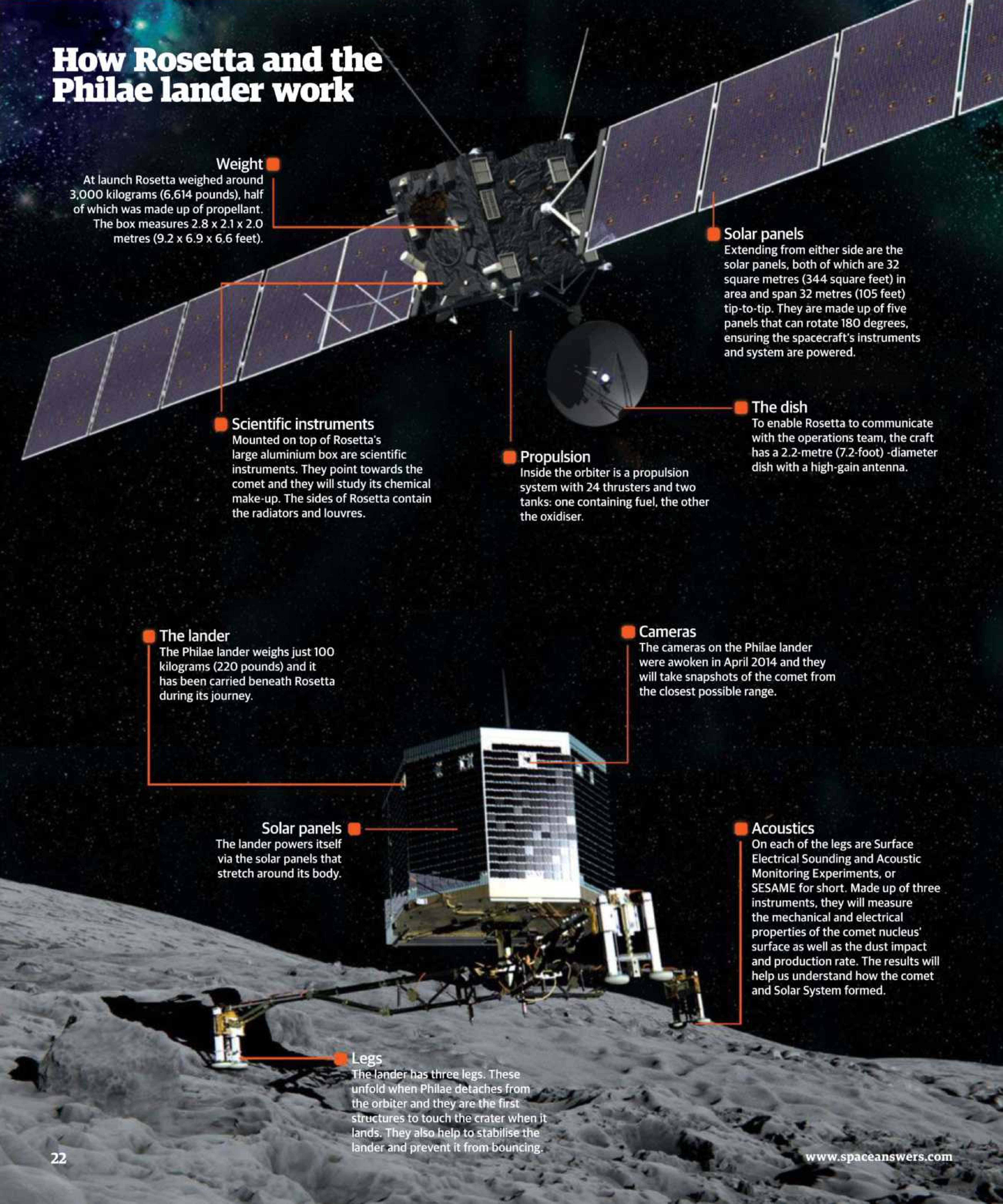
Was the hibernation period challenging?
It was a fairly unique thing to do. We essentially powered it down and didn't have any communication with it for two and a half years. There was a psychological barrier to get through because we didn't know what was going on and we were waiting to see if it came back alive on the appointed day.

It must have been a relief when it did...
From a kind of scientific point of view, there was every reason to believe everything was going fine but from a psychological view two and a half years is a long time. It was an incredible relief and the day was very tense for everybody.

Are you particularly excited about landing on the comet itself?
The lander is an important part of the mission but it's very much an added extra. The spacecraft itself has lots of instruments on board and it will be flying with the comet and measuring it, so even without the lander it's a very valuable mission.

Would extending the mission beyond 2015 be an issue for the team?
2015 takes us beyond the point where the comet passes closest to the Sun, so from then on we're going back out again, but we're doing the same science and I'm sure all of the scientists once we're there will have further things they want to see that they didn't get chance to investigate before. We don't have a problem power-wise until into 2017. Essentially, as long as the spacecraft has survived, there's no reason not to extend for at least a year.

How Rosetta and the Philae lander work



Weight
At launch Rosetta weighed around 3,000 kilograms (6,614 pounds), half of which was made up of propellant. The box measures 2.8 x 2.1 x 2.0 metres (9.2 x 6.9 x 6.6 feet).

Solar panels
Extending from either side are the solar panels, both of which are 32 square metres (344 square feet) in area and span 32 metres (105 feet) tip-to-tip. They are made up of five panels that can rotate 180 degrees, ensuring the spacecraft's instruments and system are powered.

Scientific instruments
Mounted on top of Rosetta's large aluminium box are scientific instruments. They point towards the comet and they will study its chemical make-up. The sides of Rosetta contain the radiators and louvres.

Propulsion
Inside the orbiter is a propulsion system with 24 thrusters and two tanks: one containing fuel, the other the oxidiser.

The dish
To enable Rosetta to communicate with the operations team, the craft has a 2.2-metre (7.2-foot) -diameter dish with a high-gain antenna.

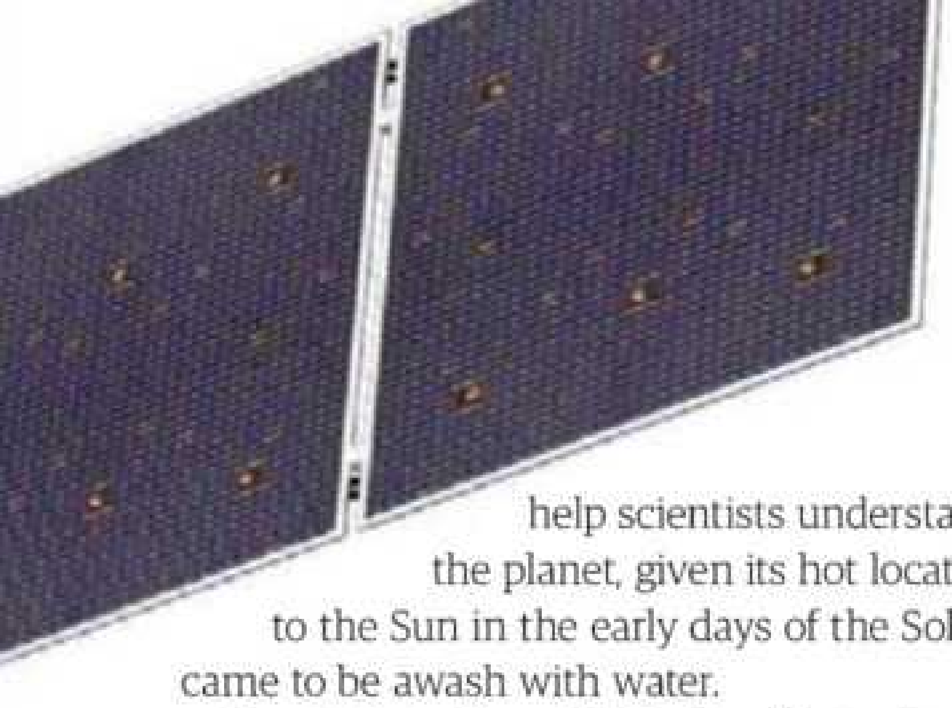
The lander
The Philae lander weighs just 100 kilograms (220 pounds) and it has been carried beneath Rosetta during its journey.

Cameras
The cameras on the Philae lander were awoken in April 2014 and they will take snapshots of the comet from the closest possible range.

Solar panels
The lander powers itself via the solar panels that stretch around its body.

Acoustics
On each of the legs are Surface Electrical Sounding and Acoustic Monitoring Experiments, or SESAME for short. Made up of three instruments, they will measure the mechanical and electrical properties of the comet nucleus' surface as well as the dust impact and production rate. The results will help us understand how the comet and Solar System formed.

Legs
The lander has three legs. These unfold when Philae detaches from the orbiter and they are the first structures to touch the crater when it lands. They also help to stabilise the lander and prevent it from bouncing.



help scientists understand how the planet, given its hot location close to the Sun in the early days of the Solar System, came to be awash with water.

Rosetta's studies will also be able to discern levels of glycine, a pre-protein molecule that's been shown to exist on comets in a number of previous missions. "Comets were made up of these complex molecules that are the building blocks for protein and so the building blocks for DNA," Taylor explains. "Comets could have also delivered building block materials for life, to Earth."

Although such investigations are ongoing, Rosetta has been giving more than enough information for scientists to work with so far. Quite aside from Twitter users spotting a "human face" in the comet, of greater interest is that the comet 67P/C-G has a surface temperature of -70 degrees Celsius (-94 degrees Fahrenheit). This is warmer than was first thought, which is why the comet's ice would appear to be covered by dust. Observations show the comet may be made up of two definite components, one of which is elongated and the other more bulbous (the catalyst for the rubber duck/potato comparisons). Such objects are common and are referred to as contact binaries but it points to 67P/C-G being two comets, rather than one.

"We had thought that perhaps the comet had been eroded through previous apparitions or transitions, or possibly suffered impact erosion, but it has the appearance of a contact binary," Taylor says. "That was one of the first ticks in the box because we wanted to get an idea of what the 3D structure looked like." With that in mind, scientists can get on with mapping the comet's terrain and its gravitational field, although if 67P/C-G is a contact binary it will have two centres of gravity making manoeuvring Rosetta a touch more difficult.

Still, some breakthroughs have been made during this mission so far. Scientists have been able to detect some water sublimation and outgassing, a kind of sweating process that produces a characteristic atmosphere (67P/C-G can sweat off as much as 300 millilitres of water every second). They have spotted cliffs that are 100 metres (328 feet) tall. Along with steep slopes and precipices, there are deep pits, smooth plains and rocks with sharp edges. If it weren't for Rosetta's proximity, we would never see such detail. "From an observation perspective we are getting very high-resolution images of the surface," says Taylor. "In terms of resolution, it can be down to 50 centimetres [20 inches]."

Very soon the resolution will be even greater. The Rosetta mission aims to get so close that it will, in November, seek to send a lander onto the comet's surface. This will unlock so much more knowledge, enabling experts to fully understand these objects in general and how they interact. Sniffing a comet is one thing, the scientists say, but scratching the surface is quite something else. A landing site known as "J" on the head of the comet has been chosen, a task that has not been easy because scientists are aiming for the most perfect position, but they have just one shot. The lander will be released from a height of around a kilometre up (0.6 miles). When it's anchored to the comet's nucleus, it will send high-resolution images and information about the comet's ices and organic crust to the orbiter, which will store them for transmission back to Earth.

Just one of Rosetta's 32-metre wings. This was taken in May 2002, as the spacecraft was being checked in for testing, two years before its launch.

"Along with steep slopes and precipices, there are deep pits, smooth plains"

"The lander is the cherry on top," says Taylor. "That really puts us as close as we can to the comet and it lets us dig into that primordial material. By riding along, then detecting material coming off the comet and by actually landing on it, we can get to grips with its whole evolutionary process. It will show us why comets are important.

"Because we look at comets as being time capsules from the early formation of the Solar System, any material therein could have been locked in from ancient times," Taylor continues. "We're sampling that in as pristine a state as possible, because the closer you get, the less processed it is. By landing on the surface, it gives us the best idea of how and what material was around at the time of the early Solar System. It also indicates where that comet came from in the early Solar System."

The headache posed by the lander has overtaken the main concerns expressed during the month before Rosetta went into orbit. Scientists have been desperately looking for an area free of rocks, craters and holes. Crucially, they want somewhere with soft ground so that the probe can delve deep into the comet's structure.

Back in July, the main operational decision was to work out how to fly the spacecraft around the comet. "We had a rough idea how we'd do it, but we only really knew for sure once we got up close to the comet, because it had never been done before. Nobody has ever flown or tried to orbit around a comet," says Taylor.

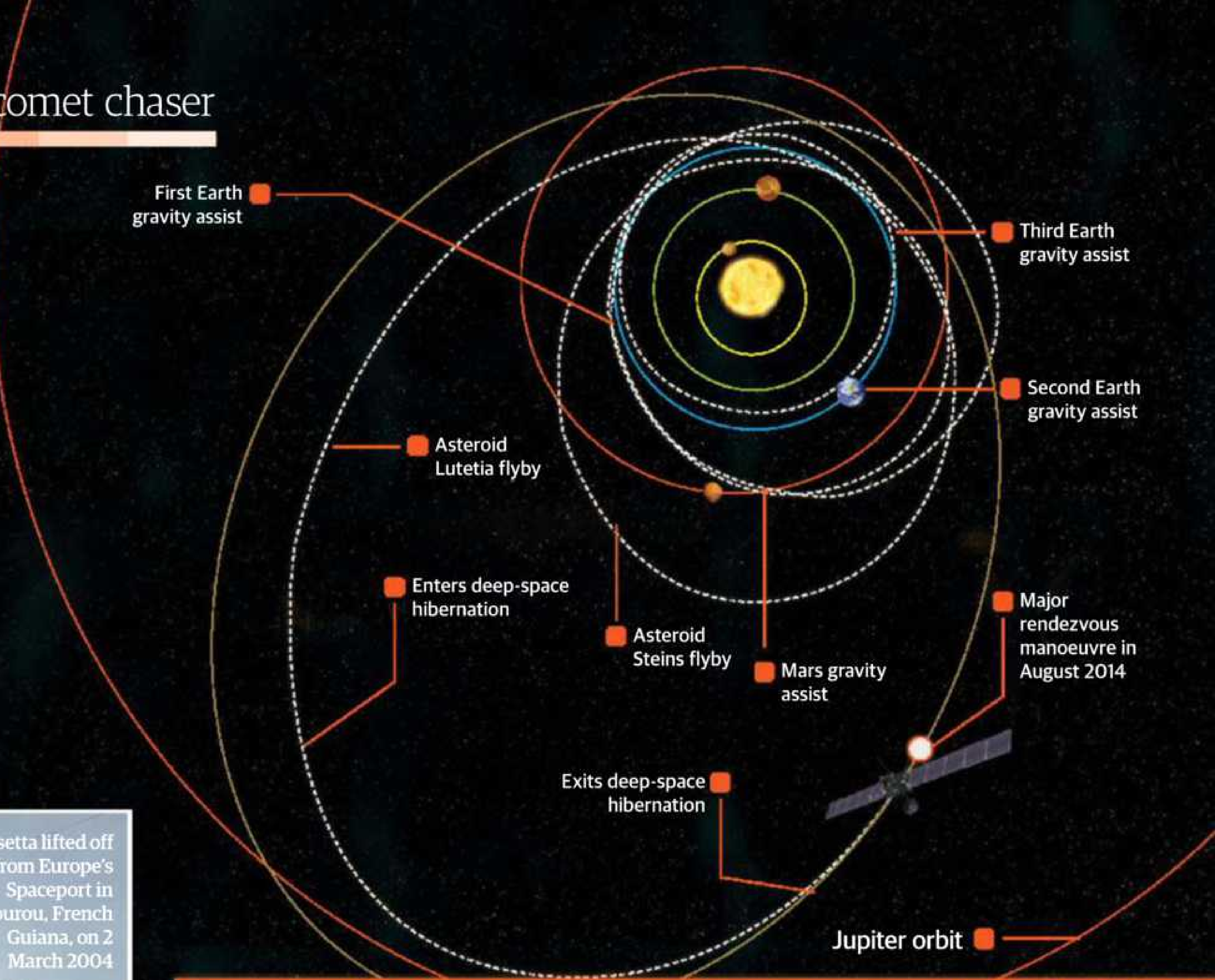
Nevertheless it has helped that 67P/C-G is a periodic comet, which is one that either has an orbital period of less than 200 years or has been observed during more than one perihelion passage. This pattern in its movements brings with it a certain level of predictability to the table. Scientists were able to use the celestial mechanics of Johannes Kepler and Joseph-Louis Lagrange, which have been in circulation for centuries. However, they also knew that this particular comet orbits the Sun once every 6.45 years and rotates once every 12.4 hours - its periodic nature is why its name is prefixed with 67P to help identity it.

"We expect comets to be unpredictable and that is natural," says Taylor. "With 67P/Churyumov-Gerasimenko, there was an increase or a burst of activity, that then went back down to a background level, but it has appeared to behave itself somewhat since then. All of this being said, we planned for two levels of activity based on previous apparitions of the comet and our understanding of comets in general from ground-based observations of how we think the activity would evolve for this particular class of comet. We have a low-activity and a very high-activity case, and we plan within that envelope of those two limits..."

As the comet nears the Sun, its behaviour will change. It will become more-active so any volatile material that's stuck inside will start a process of sublimation. This is where the frozen material changes instantly to a gaseous form and this pushes out a lot of dust. Getting closer will enable Taylor and his colleagues to see what that primordial dust

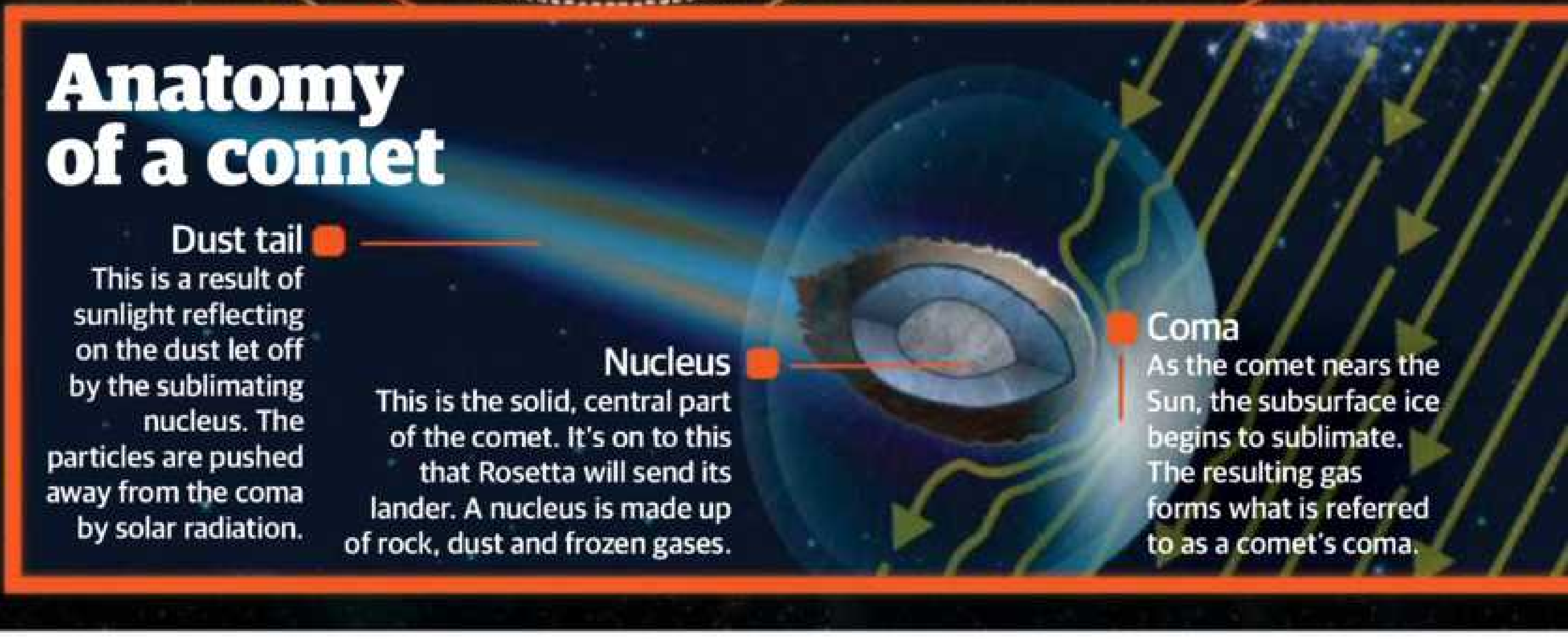
Rosetta's journey

Rosetta's journey to comet 67P/Churyumov-Gerasimenko has been a long one that has included three flybys of Earth and one of Mars. In January 2014, when Rosetta was awoken from hibernation it was around 9 million kilometres (5.6 million miles) away from comet 67P/C-G. By early May, it was two million kilometres (1.2 million miles) away. Today it flies around the comet and it's getting ready to land. Although not to scale, this image shows the craft's journey. The white lines show the trip made to-date, with the yellow line showing the comet's orbit.


First Earth gravity assist
Third Earth gravity assist
Second Earth gravity assist
Asteroid Lutetia flyby
Enters deep-space hibernation
Asteroid Steins flyby
Mars gravity assist
Major rendezvous manoeuvre in August 2014
Exits deep-space hibernation
Jupiter orbit

Rosetta lifted off from Europe's Spaceport in Kourou, French Guiana, on 2 March 2004

Anatomy of a comet



Dust tail
This is a result of sunlight reflecting on the dust let off by the sublimating nucleus. The particles are pushed away from the coma by solar radiation.

Nucleus
This is the solid, central part of the comet. It's on to this that Rosetta will send its lander. A nucleus is made up of rock, dust and frozen gases.

Coma
As the comet nears the Sun, the subsurface ice begins to sublimate. The resulting gas forms what is referred to as a comet's coma.

contains, what some of the molecules are and also how that interaction works.

Being so close to the comet will allow scientists to scrutinise the nucleus and look at differential activity on various parts of the surface. In doing so, scientists will begin to see the formation of the coma, the nebulous envelope that is around a comet's nucleus. Not only that but they will be able to get right inside it, testing it to find out what's beneath.

Taylor admits that, at its heart, the mission is about understanding how a comet works. "The tails are formed due to the interaction of the solar wind and solar radiation, so we're going to be interested to see the evolution of the surface of the nucleus in terms of that activity. The question for us is whether there are local regions of enhanced activity and what that means for cometary science. This is a big thing for Rosetta - the ability to see if there is evolution of the particles and molecules within that material..."

The comet will be in its closest approach to the Sun in August 2015 and the mission is due to end in December 2015, but there is already talk of an extension. "It's limited by how much fuel we have on board and ultimately you'll get to a stage... When you're so far away from the Sun again that Rosetta would go into hibernation again..." Taylor explains.

"[With an extension] we'd get more unique science, because we'd start to look at what the comet does as it moves away from the Sun," he continues. "We'd see the activity shown by the comet as it reaches the Sun starting to reduce. We'd also be able to scrutinise the nucleus of the comet better once the coma starts to die down, actually looking at the three-dimensional structure and seeing how that has changed in this transition through the Sun."

Seeing how the Solar System evolved, the material that was potentially around to make up the Sun, the origins of the comets and the knowledge they can impart when investigating exoplanetary systems, will give scientists a better idea of how Earth-like planets exist. "For me it's unlocking code," says Taylor. "It's really understanding how a comet works, what it's made from and making that link to solar system formation and evolution." The future looks exciting. ●

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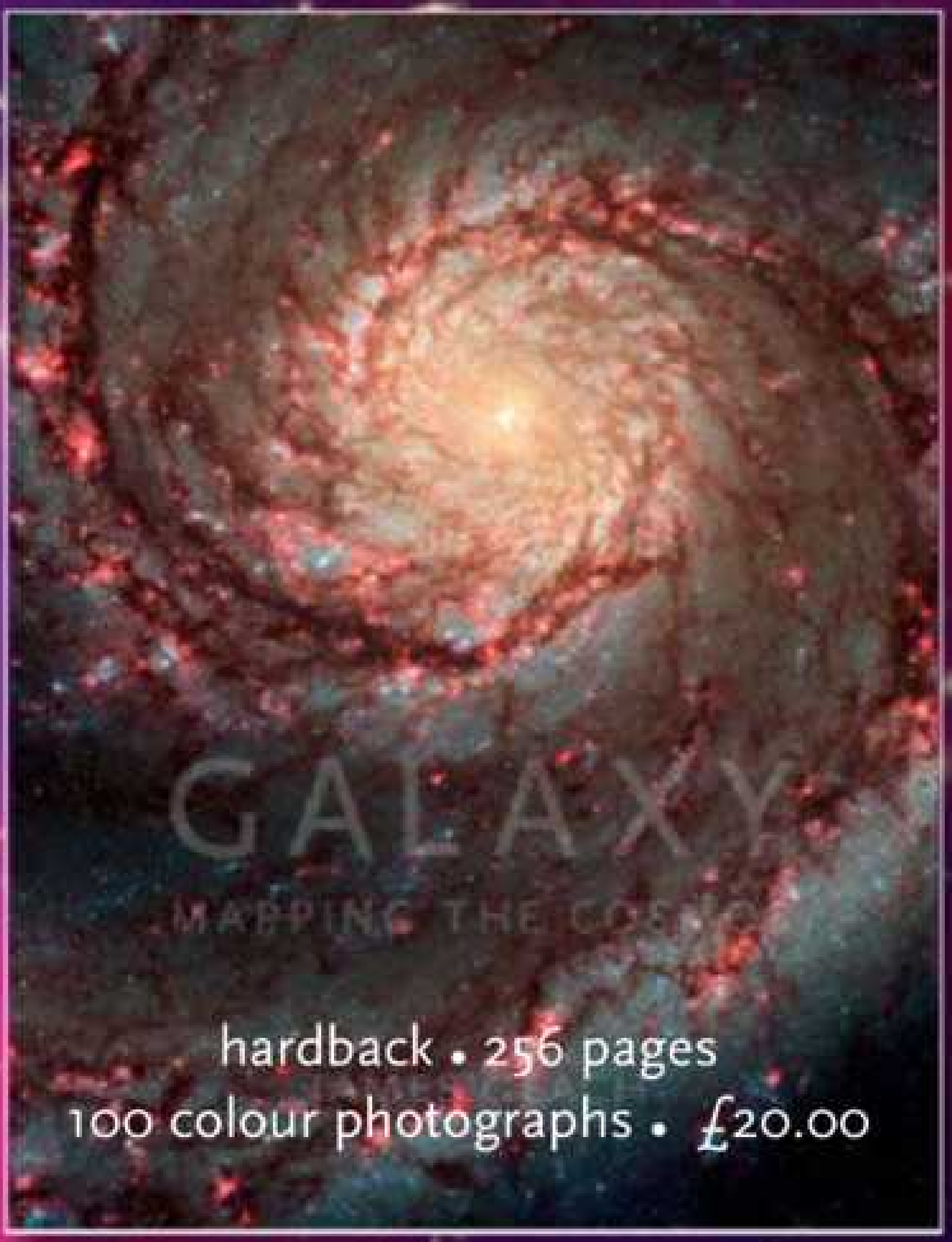
GALAXY

MAPPING THE COSMOS

James Geach



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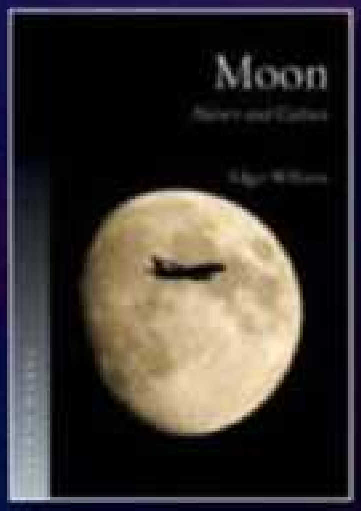

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Planet core simulator

Could there be giant diamonds inside Neptune? Scientists have replicated the conditions at a giant planet's core to find out

The extreme temperatures and pressures inside the core of Neptune make visiting it virtually impossible, so the best we can do at the moment is simulate its extreme environment using Earth-based lasers.

Scientists at the US National Ignition Facility (NIF) have focused their work on the conditions inside Neptune to understand more about it and the formation of gas giant planets in our Solar System. In addition, the vast majority of exoplanets discovered by the Kepler space mission are of a similar size and probably have similar characteristics to Neptune (such as 55 Cancri e, which is 40 light years away from us), so any insights can be applied to them too.

The decomposition of methane and other elements of its atmosphere under enormous heat and pressure might have created a diamond core inside Neptune, and it may well rain diamond crystals inside its atmosphere.

Earlier experiments conducted using the Omega Laser (a device that focuses 60 powerful lasers on to a target just one millimetre or 0.004 inches in diameter) at the University of Rochester, New York, indicated that under extreme heat and pressure diamonds turn into liquid carbon. Small chunks of diamond float in the liquid, like ice in water.

This led to speculation by Jon Eggert of the Lawrence Livermore National Laboratory that Uranus and Neptune could have liquid carbon cores with huge chunks of diamond 'bergs' floating around them. These diamond-encrusted seas might deflect the magnetic fields at their core, and explain why both planets have magnetic poles that aren't aligned with their rotational axes.

To carry out the latest research at the NIF a technique called 'dynamic ramped compression' was used. This involves firing 176 laser beams that are mounted inside a spherical aluminium target chamber, at a small diamond positioned inside a gold cylinder at the centre of the chamber.

The energy produced by the lasers created a pressure wave 50 million times the Earth's atmospheric pressure (five terapascals) that easily vaporised the diamond in less than 10 billionths of a second. That time span makes the blink of an eye seem like an eternity and is an incredible feat when you consider that diamonds are the hardest substance found in nature.

The combined energy of the lasers (0.76 megajoules) on the carbon crystal compressed it to a density greater than lead, with a pressure 14 times that at the centre of our planet – very similar to the densities found at the core of Saturn.

Certainly, this research is also able to provide a few additional insights into the nature of the core structures of the gas giant planets of our Solar System – Saturn and Jupiter. Currently there are two basic theoretical models that are used to explain the formation of these planets.

The core accretion model proposes that Jupiter originally had ten times the mass of Earth, and huge gravitational forces caused it to accumulate and trap a thick hydrogen atmosphere.

The giant instability model considers that instabilities in density caused gravitational fluctuations that clumped hydrogen gas together, without the need for a core structure.

One challenge was to keep the temperature low enough to replicate the conditions on gas giant planets, which they achieved by precisely adjusting the laser intensity. As the pressure was increased, the density, sound and stresses taking place in the crystal carbon were carefully monitored.

It was expected that they would see a series of phase transitions as the crystal became denser, but nothing of this nature was detected. Why these transitions do not occur is something of a puzzle at the moment.

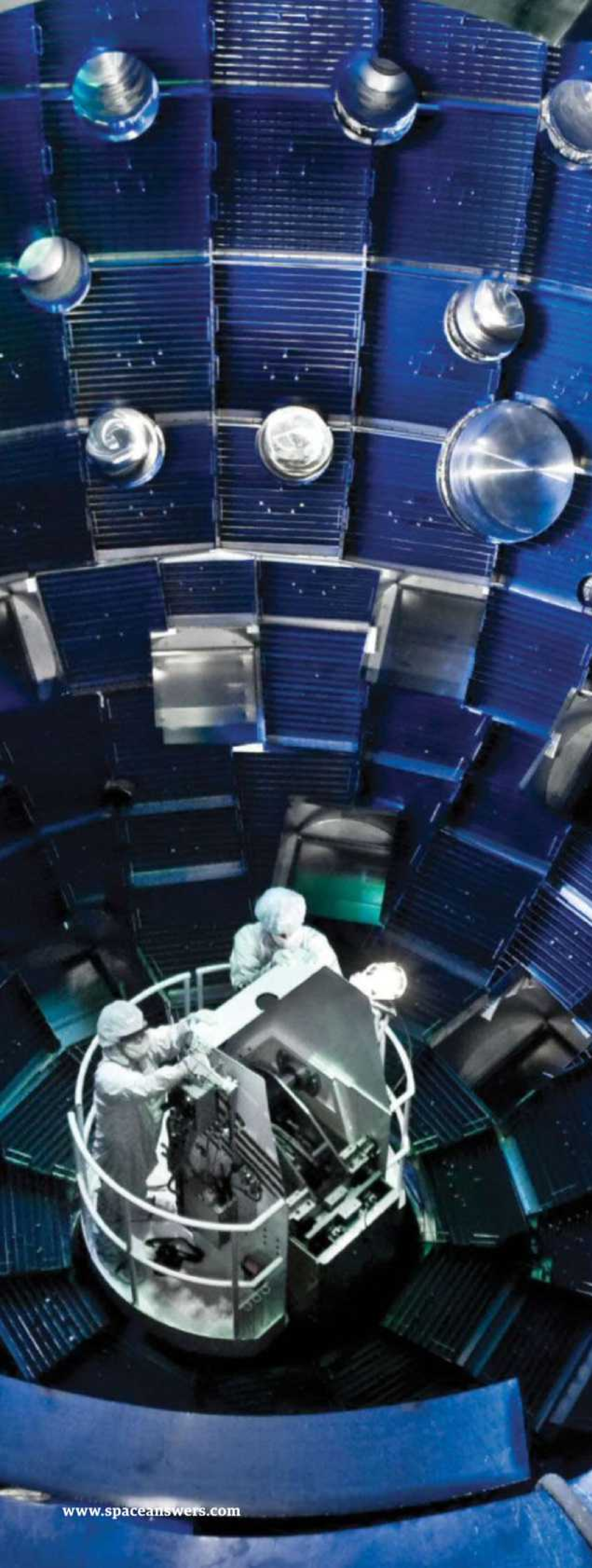
This research can only give us a brief glimpse at what happens to matter inside these environments and the conditions found there. In the real world these planet-forming processes take place over millions of years, involving many complex and unique interactions. We also need to know how the elements in the upper atmosphere of planets mix or separate as we get closer to their core.

So there is still plenty of scope for researchers to simulate alien environments as accurately as possible and by doing so, theoretical models about the formation of gas giants can be more rigorously tested and refined. ●

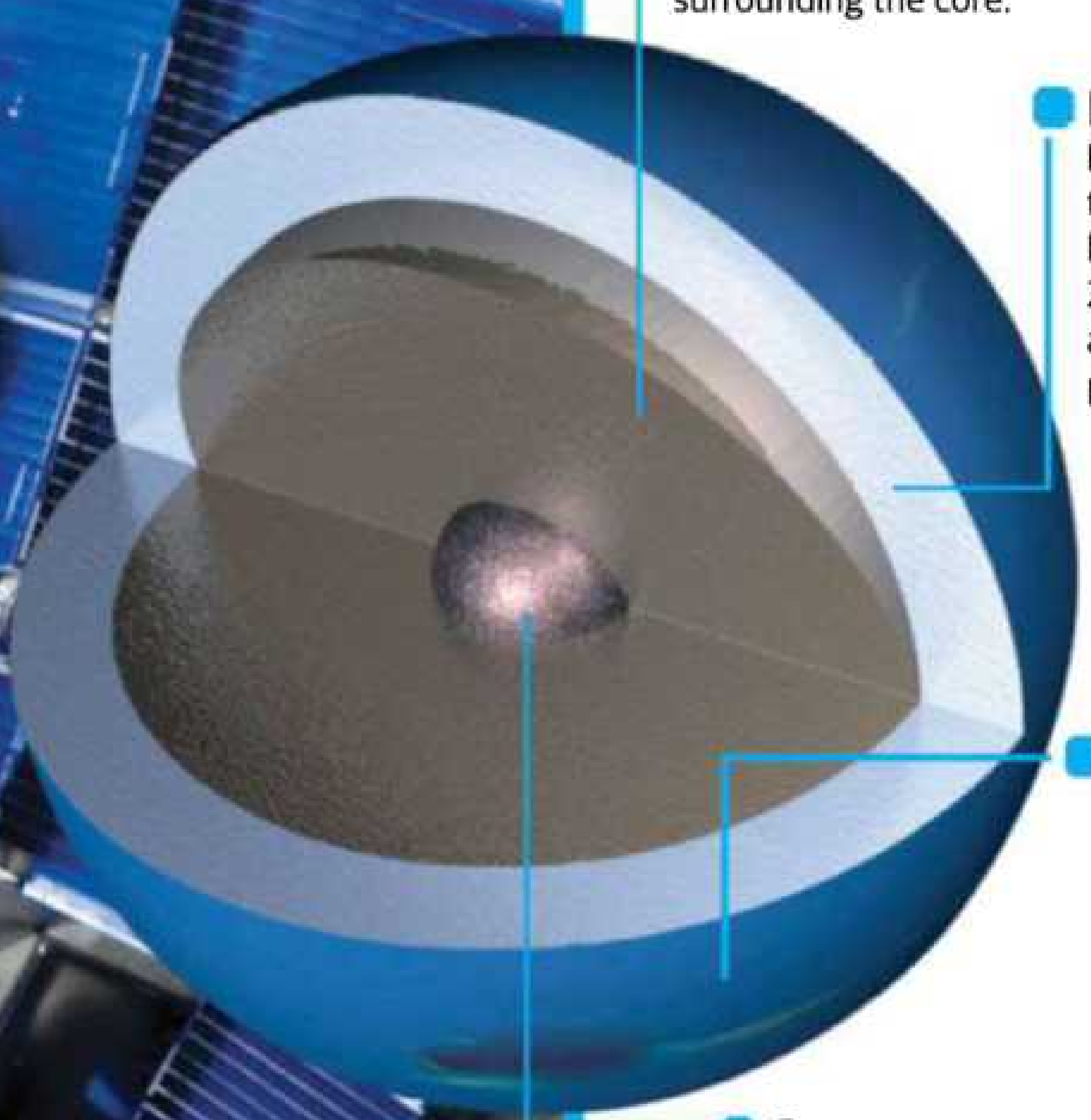
> "The energy produced by the lasers created a pressure wave 50 million times the Earth's atmospheric pressure"

A technician centres the target positioner, so that the lasers hit the exact area inside the 10m (33ft) diameter target chamber

Technicians use a service module to gain access to the target chamber at the National Ignition Facility, enabling them to set up and inspect experiments



Inside Neptune



Mantle
This subsurface layer is composed of a mixture of hot, thick water (H_2O), ammonia (NH_3), and methane (CH_4), ten times the mass of Earth surrounding the core.

Ice giant
Four times bigger than Earth, Neptune has a radius of 24,622km (15,299mi), and is the furthest planet from the Sun.

Atmosphere
The main constituents are hydrogen (H_2), helium (He) and methane (CH_4). The methane in its stormy atmosphere gives it an intense blue appearance.

Core
Neptune's iron and silicate core has a similar mass and size as Earth. Research at NIF suggests it could also be composed of diamonds created by the intense pressure and heat.

National Ignition Facility

The National Ignition Facility (NIF) is a US government-funded project to 'study inertial confinement nuclear fusion', with the aim of providing new forms of energy production. The 150-ton, aluminium, spherical target chamber was installed in a seven-storey-high target bay and coated with boron-injected concrete (an element commonly used for shielding nuclear reactors) to absorb neutrons.

Holes in the chamber provide viewing ports and access to 192 laser beams that fire at the centre of the chamber. A specially built robotic assembly machine precisely makes targets that have the correct density, shape and smoothness for NIF experiments. When operating at its peak, the facility uses more than 500 trillion watts of power.

Incidentally, the futuristic appearance of the target chamber made it ideal for being used as the warp core of the Starship Enterprise in the *Star Trek: Into Darkness* film.

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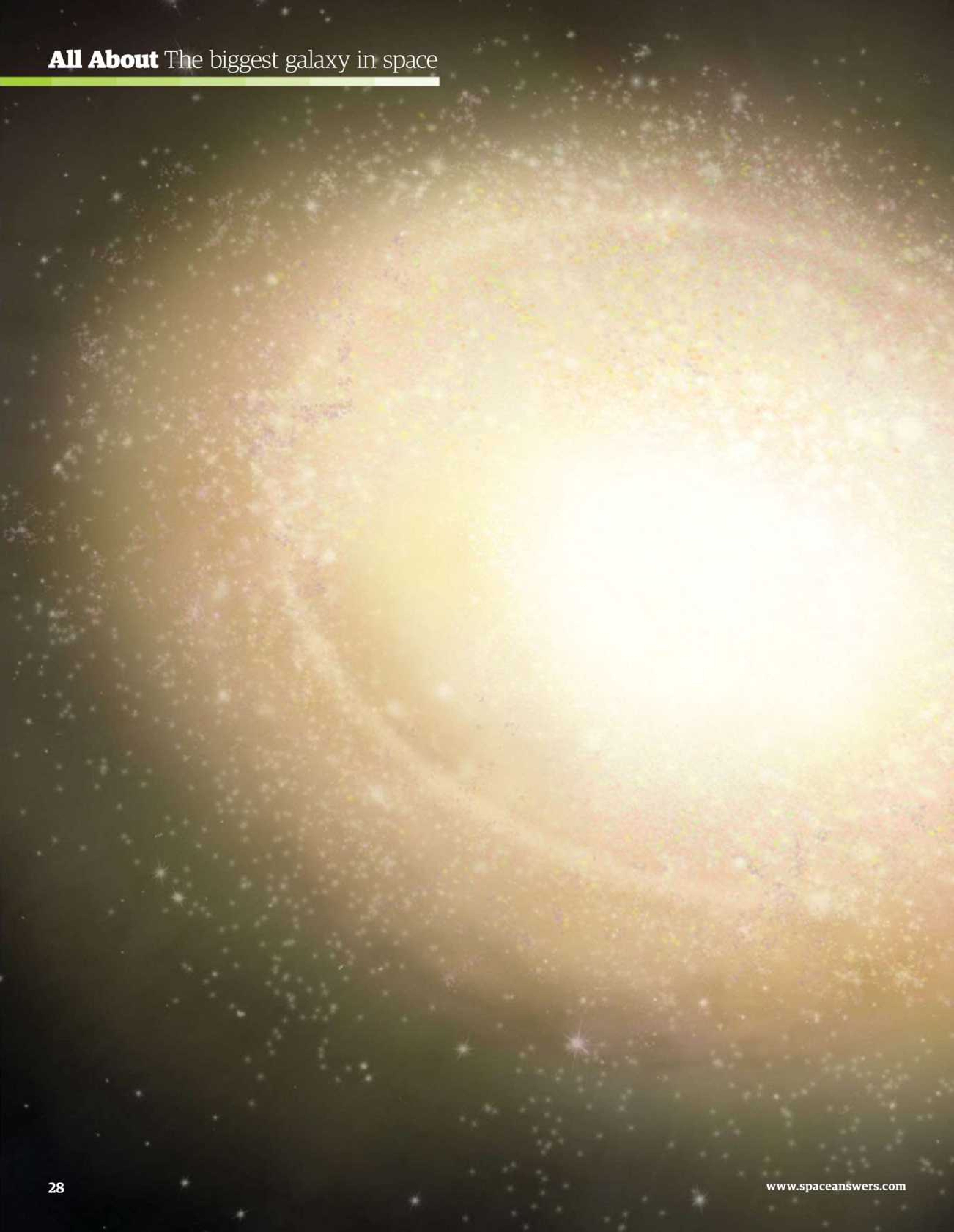


All About...
THE BIGGEST GALAXY IN SPACE

A billion light years from the Earth lies an elliptical supergiant of incredible proportions: IC 1101 is the largest known galaxy in the universe, illuminated by the glow of 100 trillion stars

Written by Laura Mears

The stars that adorn the night sky might be light years apart, but they do not exist in isolation. They are bound up in dark matter, caught in a mutual gravitational waltz that sees them drawn in slow orbits around the centres of enormous galaxies. The galaxies themselves collect together in groups, and the groups form clusters.

Within clusters, galaxies come close enough to interact, feeding on one another in acts of galactic cannibalism, and accumulating vast quantities of dust, gas and stars in violent mergers. The end products of the most spectacular collisions are the supergiant elliptical galaxies, some of which number among the largest galaxies in the known universe.

At over 30 times the diameter of the Milky Way, the unimaginatively named IC 1101 holds the title of 'largest galaxy', spanning a region of space measuring around 3 million light years. First recorded in the 1890s by astronomer Lewis Swift, it was later catalogued as a 'nebulous feature' by John Louis Emil Dreyer and remained an unidentified cloud of dust and gas for several years. By the Thirties Edwin Hubble had begun identifying some of these 'nebulae' as galaxies, so it wasn't long before the true identity of IC 1101 was revealed.

The enormous galaxy is located just over a billion light years away between the constellations of Virgo and Serpens; easily found by following the arc of the Big Dipper southeast towards the bright star Arcturus, and just northeast of the brightest star in Virgo, Spica.

Virgo is the second largest constellation in the night sky, and is home to the Virgo cluster, a large group of interacting galaxies just over 50 million light years from the Earth. The cluster contains a spectacular array of objects, including one of the most massive supergiant elliptical galaxies in the known universe, M87. Barely wider than the Milky Way, this dense galaxy has an estimated 1,000 times more mass.

Far in the distance, beyond these nearby galaxies, a much larger object can be seen from the ground: the Abell 2029 galaxy cluster, and at its centre, IC 1101. Abell 2029 is vast. Its outline spans several million light years, encompassing thousands of galaxies. In order to hold itself together it must contain dark matter with a mass equivalent to over a hundred trillion Suns. The unseen matter traps a halo of gas, superheated to millions of degrees and visible as a diffuse envelope of X-rays.

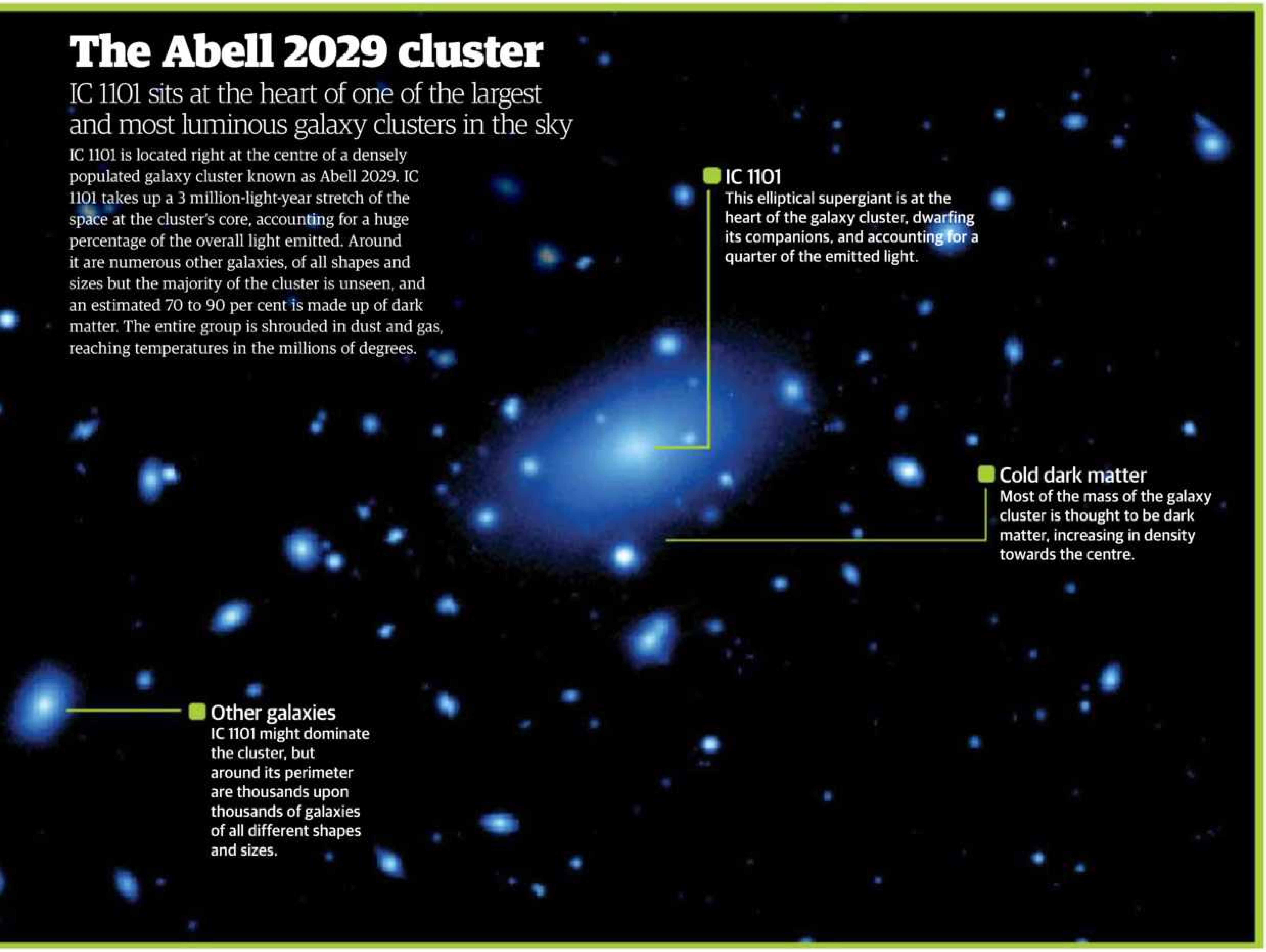
The galaxies in the cluster are not evenly distributed and the core is dominated by IC 1101, a type-cD galaxy with a halo of stars and an enormous dustless envelope. Though it is just one of the thousands of galaxies in Abell 2029, IC 1101 accounts for a significant proportion of the entire cluster's diameter and total light emitted, effortlessly earning it the title 'brightest cluster galaxy' (BCG), the most luminous object in Abell 2029.

Other supermassive galaxies have been identified, but none are able to compete with the vast outline of IC 1101. It dwarfs every other galaxy identified to date. The largest spiral galaxy, NGC 6872, has two spiral arms, the tips of which are a staggering 522,000 light years apart, but even at that size, it is less than a fifth of the width of IC 1101. ■

The Abell 2029 cluster

IC 1101 sits at the heart of one of the largest and most luminous galaxy clusters in the sky

IC 1101 is located right at the centre of a densely populated galaxy cluster known as Abell 2029. IC 1101 takes up a 3 million-light-year stretch of the space at the cluster's core, accounting for a huge percentage of the overall light emitted. Around it are numerous other galaxies, of all shapes and sizes but the majority of the cluster is unseen, and an estimated 70 to 90 per cent is made up of dark matter. The entire group is shrouded in dust and gas, reaching temperatures in the millions of degrees.



IC 1101
This elliptical supergiant is at the heart of the galaxy cluster, dwarfing its companions, and accounting for a quarter of the emitted light.

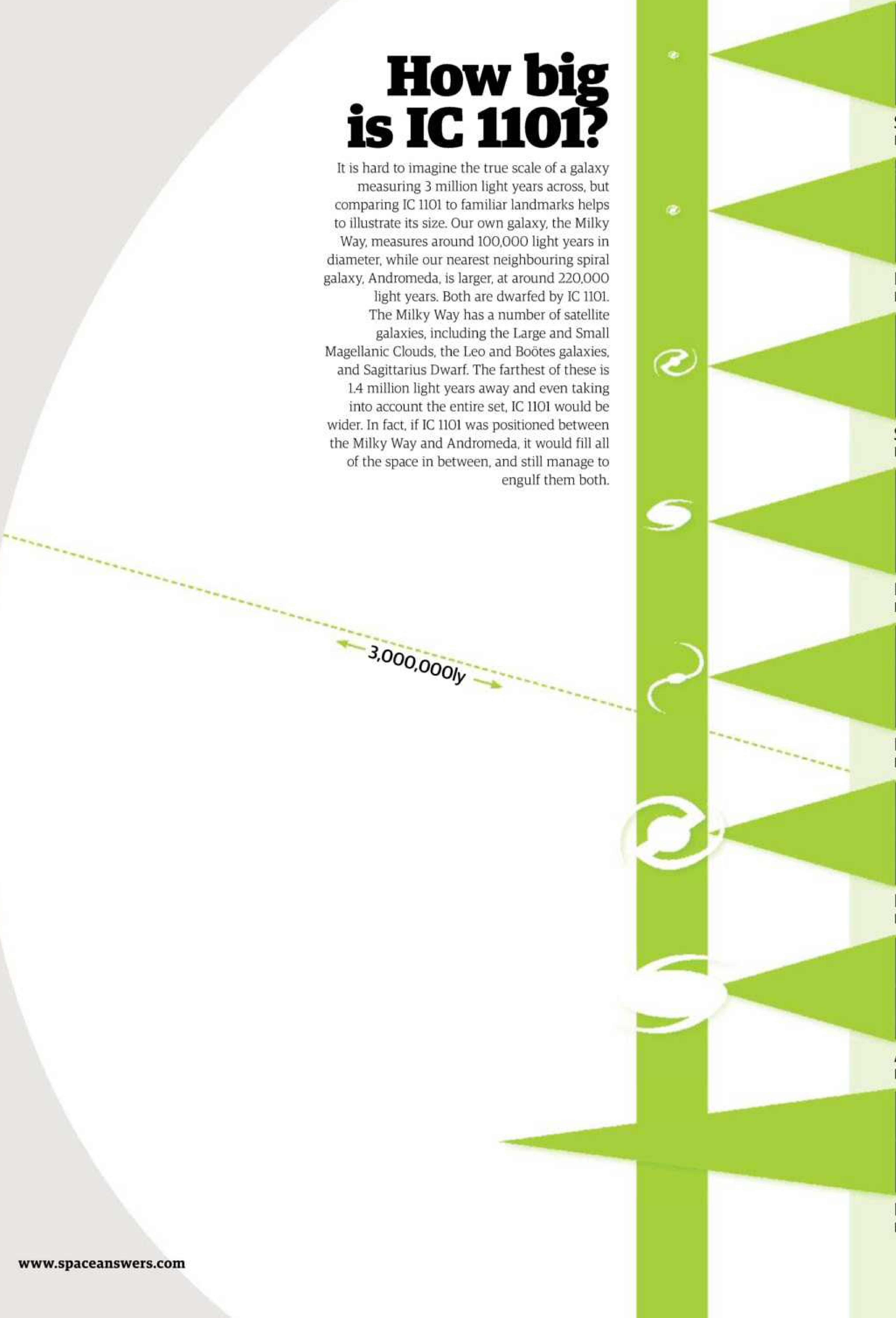
Cold dark matter
Most of the mass of the galaxy cluster is thought to be dark matter, increasing in density towards the centre.

Other galaxies
IC 1101 might dominate the cluster, but around its perimeter are thousands upon thousands of galaxies of all different shapes and sizes.

How big is IC 1101?

It is hard to imagine the true scale of a galaxy measuring 3 million light years across, but comparing IC 1101 to familiar landmarks helps to illustrate its size. Our own galaxy, the Milky Way, measures around 100,000 light years in diameter, while our nearest neighbouring spiral galaxy, Andromeda, is larger, at around 220,000 light years. Both are dwarfed by IC 1101.

The Milky Way has a number of satellite galaxies, including the Large and Small Magellanic Clouds, the Leo and Boötes galaxies, and Sagittarius Dwarf. The farthest of these is 1.4 million light years away and even taking into account the entire set, IC 1101 would be wider. In fact, if IC 1101 was positioned between the Milky Way and Andromeda, it would fill all of the space in between, and still manage to engulf them both.



SMC
Diameter: 7,000ly

LMC
Diameter: 14,000ly

Sculptor
Diameter: 70,000ly

Bode's galaxy
Diameter: 95,000ly

Milky Way
Diameter: 100,000ly

NGC 1365
Diameter: 200,000ly

Andromeda
Diameter: 220,000ly

IC 1101
Diameter: 3,000,000ly

Inside and out

The sheer scale of this galactic daddy is evidence of its violent past

The largest galaxies in the universe are the supergiant ellipticals. Many were once orderly spiral galaxies but violent collisions have distorted their outlines, disrupting their structure and burning through their remaining fuel.

Around the edges of IC 1101, a faint envelope marks the remnants of the galaxies that were obliterated by the supergiant. In the centre, low-mass stars move in chaotic orbits, burning with a gentle yellow-orange glow that indicates that they are nearing the end of their lives.

Elliptical galaxies are divided into eight classes according to their shape, with '0' being almost spherical and '7' being extremely elongated. According to this sequence, known as the 'Hubble Tuning Fork', IC 1101, with its fat and slightly flattened core, is classed as an E3.

IC 1101 is located right at the centre of the Abell 2029 galaxy cluster, a position perfect for accumulating matter, but it is possible that it wasn't always there. As a large galaxy moves through a cluster, it interacts with its smaller neighbours, accumulating a tail of galaxies and dark matter caught up in its gravitational wake. These smaller galaxies pull back against their larger captor, slowing its motion by a process known as dynamical friction. As the large galaxy slows down, it spirals towards the centre of the cluster, dragging all of the trailing galaxies with it.

At this central point, they begin to collide. As galaxies crash through one another, their gas and dust mixes, and their structures become distorted. Amid the chaos, a flurry of star formation is triggered, draining the remaining resources of the merging galaxies.

This can be seen in the Antennae Galaxies, a pair of interacting spirals found in the constellation of Corvus. In the early stages of a merger, their dust and gas is beginning to collide, resulting in an impressive starburst as matter comes together to form new stars.

The centre of IC 1101 is radio bright, indicating the presence of a supermassive black hole. This is a feature typical of most large galaxies and as they spiral towards a collision, the interaction between these enormous masses plays a significant role in shaping the new, combined galaxy. The intense interaction is strong enough to jettison entire star systems from the merging galaxies, flinging them outwards into space. The hungry black holes strip what remains, feeding on the dust and gas left over after the merger.

What is left is an elliptical core of ageing stars and a dustless envelope. The signatures of past collisions are evident in this halo, with recent or ongoing mergers creating obvious clumps. Some supergiant elliptical galaxies continue to grow gradually, accumulating matter from many smaller galaxies as they pass, while others form as part of a dramatic merger, before settling back into a more balanced state.

The halo surrounding IC 1101 is smooth and spread out, indicating that it has probably existed undisturbed for an extended period of time, and that it formed much earlier on in the history of the A2029 cluster in one monumental collision.

Smooth envelope
The halo enveloping the galaxy represents the remnants of past interactions. It is smooth, and free of clumps, indicating that IC 1101 has been a stable size for some time.

Radio centre
The core of IC 1101 is emitting radio waves, hinting at the presence of a supermassive black hole, a common feature of both spiral and elliptical galaxies.

When galaxies collide

This combined Spitzer and Hubble image of two merging galaxies, known together as II Zw 096, highlights the infrared chaos as galaxies combine

Known as 'red and dead', elliptical galaxies represent the final stages of galaxy evolution; the product of monumental collisions between rich disc galaxies.

Although the history of IC 1101 remains unknown, similar mergers are occurring across the universe, allowing astronomers to view the stages that lead up to the creation of the largest galaxies..

The Mice Galaxies are in the early stages of a merger, and are named by virtue of the long tails of dust and gas spinning out behind them as they circle one another in a death spiral.

As galaxies get closer, clouds of dust and gas crash through one another, releasing huge amounts of energy. The disrupted matter clumps and clusters, and triggers a flurry of star formation known as a starburst. As things start to settle down, the remaining dust and gas coalesces to form a vague sphere, surrounded by a fuzzy, dustless halo, and lit by the remaining dying stars, like IC 1101.

Crowded neighbourhood
Like other supergiant elliptical galaxies, IC 1101 is in a crowded area of space, positioned at the very heart of one of the most populated galaxy clusters in the observable universe.

Elongated core
The characteristic feature of an elliptical galaxy is a central core of stars, dust, and gas, forming a squashed sphere.

Orange glow
The majority of the stars in IC 1101 are ageing, and many are older than the Sun. Most of the dust and gas has been spent, and the remaining stars are metal-rich and glow yellow-orange.

By the numbers

3,000,000

The estimated diameter of IC 1101 in light years

25

Per cent of the light emitted by the Abell 2029 cluster comes from IC 1101

14.7

The apparent magnitude of the galaxy, making it visible with ground-based telescopes

30

The minimum number of Milky Way-sized galaxies that would fit end-to-end inside IC 1101

1.07

The distance to IC 1101 in billions of light years

100 trillion

The number of stars contained within the galaxy

Imaging IC 1101

This massive galaxy is visible from Earth, even at a distance of 1 billion light years

Despite the phenomenal distance between us and the largest galaxy in the universe, the bright glow of IC 1101 is still visible from the ground.

It was first recorded by American astronomer Lewis Swift. He made a series of observations together with his son Edward from the Warner Observatory in New York in the late 19th century. It was categorised as a nebula as it was not known at the time that galaxies other than our own existed.

Over a century later the object was recorded as the 1,101st item in the Index Catalogue of Nebulae and Star Clusters by Danish-Irish astronomer John Louis Emil Dreyer. Its true nature remained a mystery until the Twenties when Edwin Hubble looked at our closest galactic neighbour, Andromeda, and for the first time he saw that the cloud contained stars. Since then, the various 'nebulous objects' in the IC catalogue have been studied more closely, and with more powerful instruments.

The most comprehensive galaxy survey of galaxy size was completed by NASA's Galaxy Evolution Explorer (GALEX) before it was decommissioned in 2012. Using ultraviolet light, it mapped the distances and sizes of thousands of galaxies, some almost as old as the universe itself and even then, no galaxy wider in diameter than IC 1101 was found.

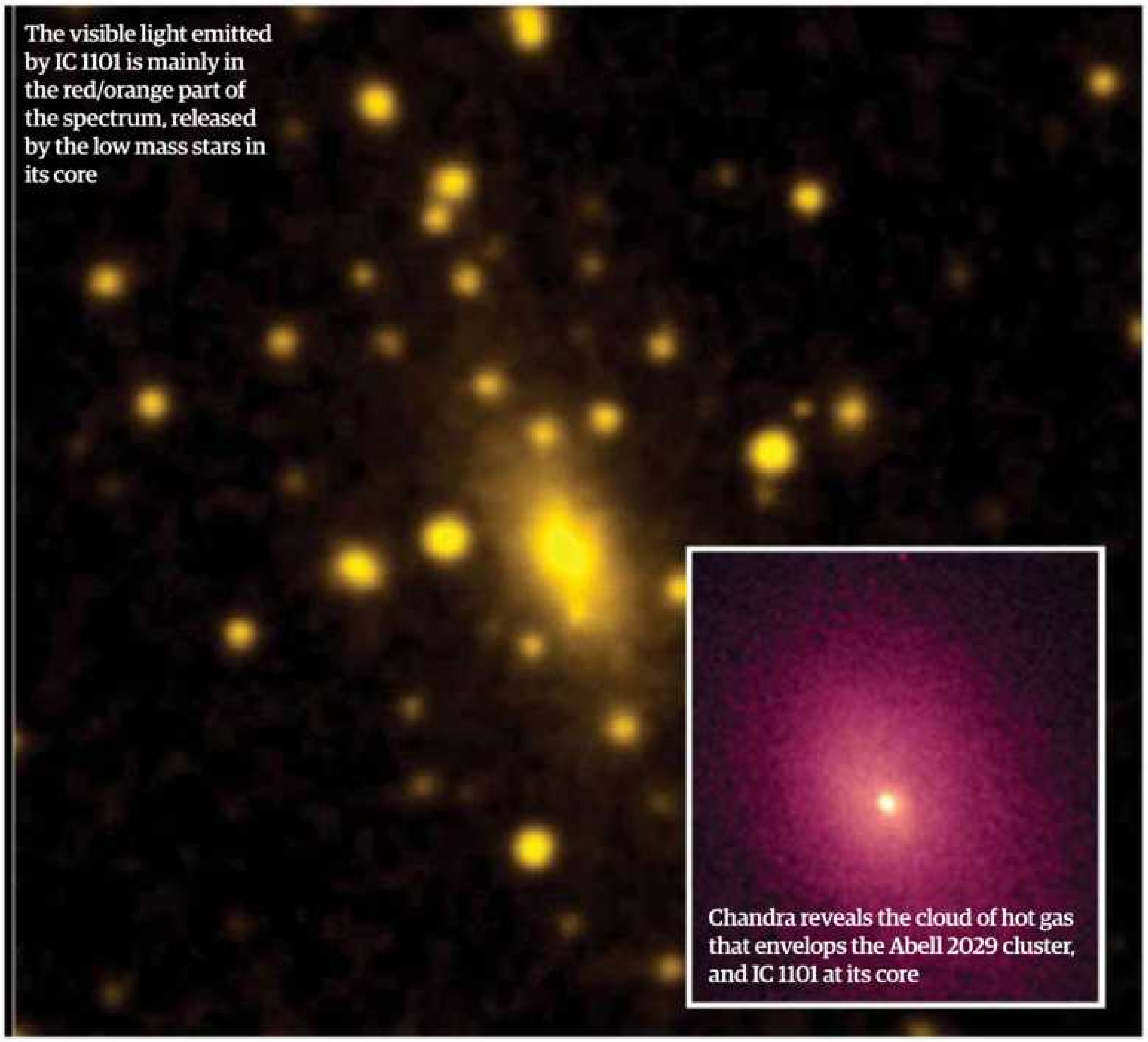
Images captured by the Kitt Peak Telescope in Arizona were the first to show the scale of IC 1101. The sheer volume of stars within the galaxy make it one of the most luminous ever identified, and at magnitude 14.7 it was easily observed with ground-based telescopes. The structure was described as large and organised, and its smooth, even outline hinted that it must be incredibly old, formed around the same time as the galaxy cluster itself, and then stabilised over the following millennia.

Much of the study of IC 1101 has been performed using radio telescopes. Radio waves are able to permeate the dust and the gas, allowing astronomers to look into the heart of the galaxy. The maps produced by telescopes reveal the core of the galaxy, indicating the presence of a supermassive black hole, and providing clues about the history of the galaxy and its parent cluster.

The Chandra X-ray Observatory has also been used to probe the hot gas that surrounds Abell 2029 and IC 1101. The halo is smooth, and increases gradually in intensity from the outer edges to the centre, representing gas heated to several million degrees. Measuring the heat and intensity has allowed astronomers to map the slow-moving, cold dark matter that clogs the core of the galaxy cluster, revealing that this mysterious substance accounts for 70 to 90 per cent of the entire mass of the cluster.

NASA's Origins programme and the James Webb Space Telescope, which is set to launch in 2018, will allow us to look back further into the history of the universe than ever before, allowing astronomers to view the earliest stages in galaxy evolution and to untangle the physics behind the formation of enormous galaxies like IC 1101. ■

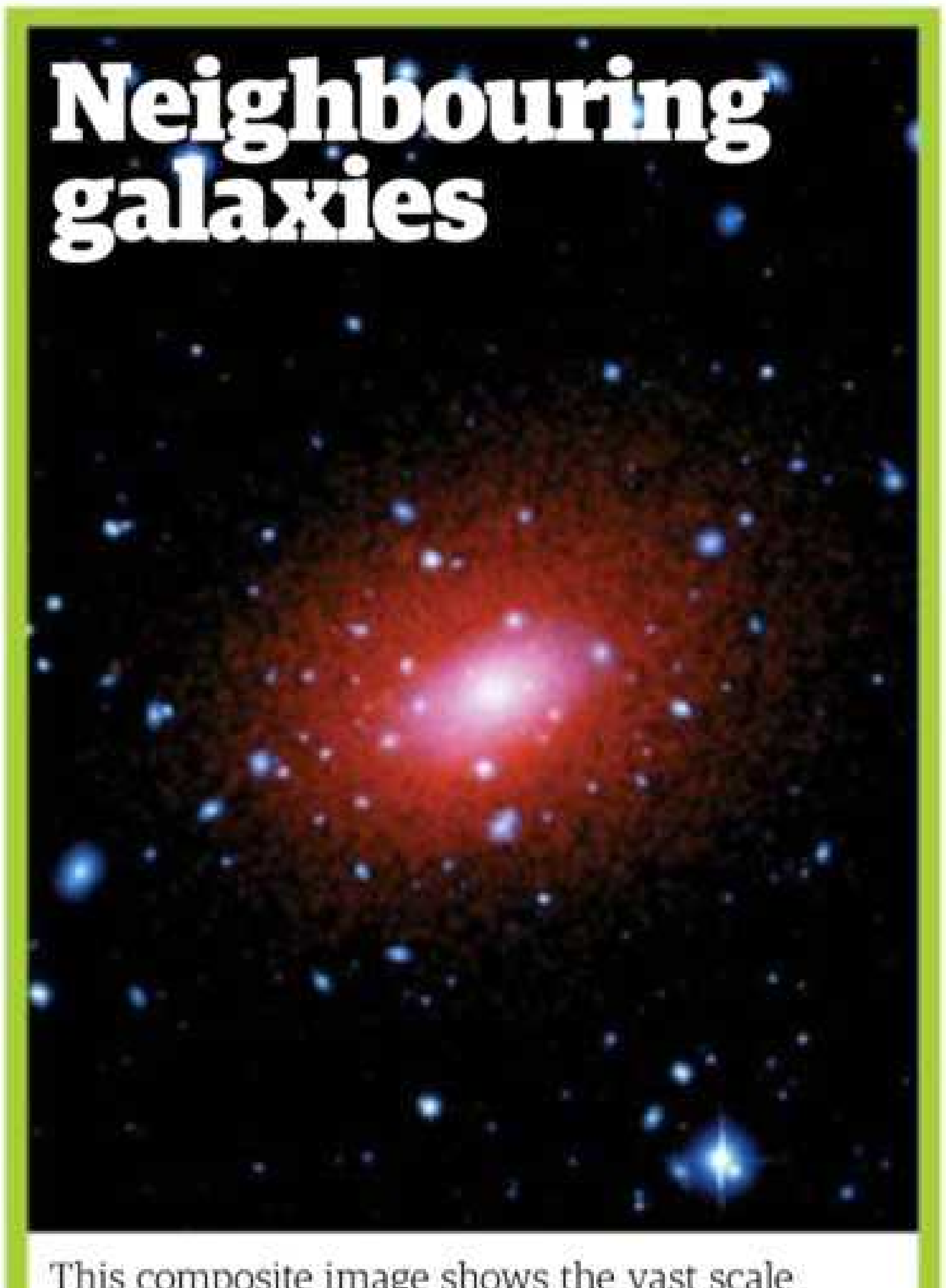
> "The maps produced indicate the presence of a supermassive black hole"



The visible light emitted by IC 1101 is mainly in the red/orange part of the spectrum, released by the low mass stars in its core

Chandra reveals the cloud of hot gas that envelops the Abell 2029 cluster, and IC 1101 at its core

Neighbouring galaxies

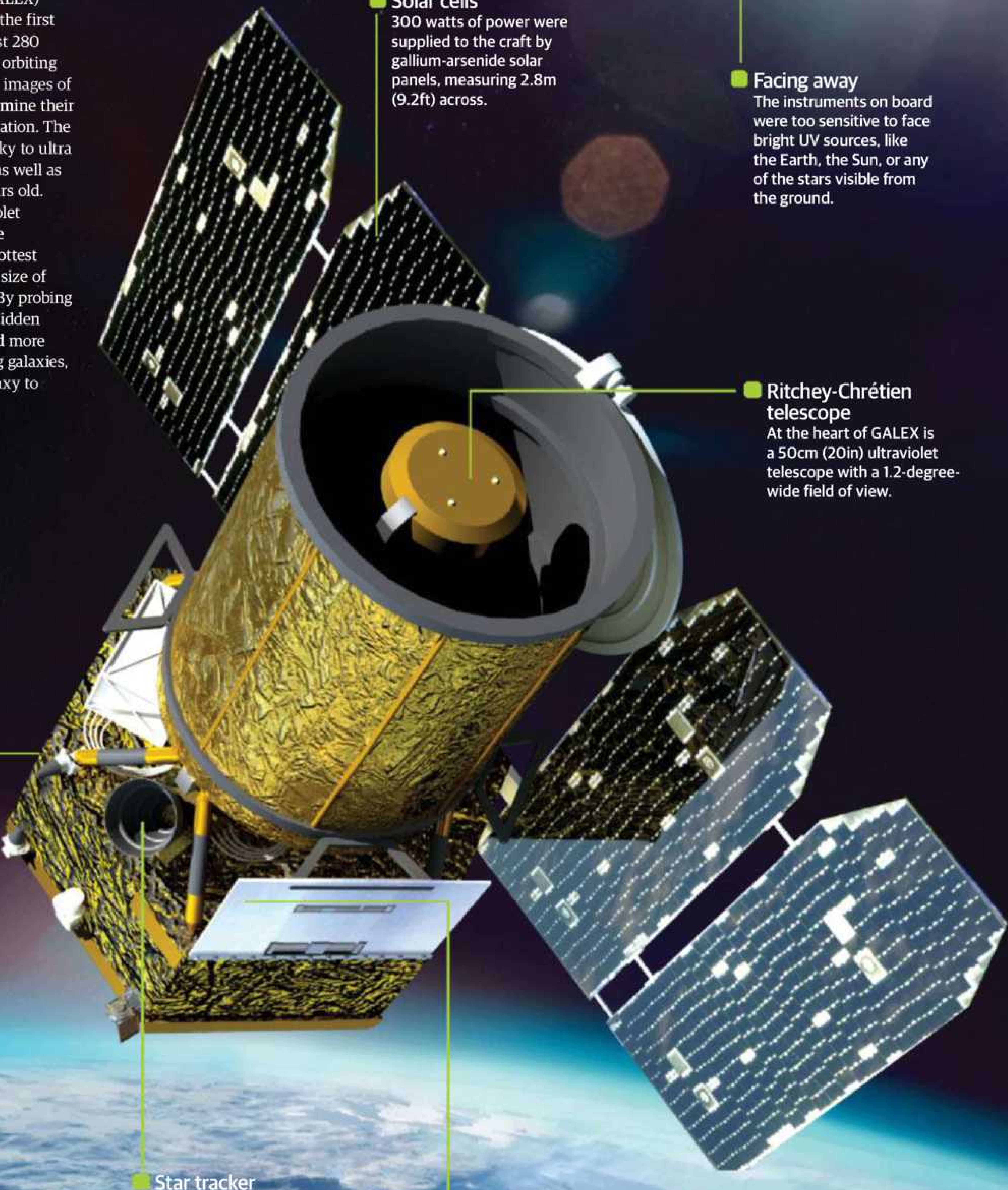


This composite image shows the vast scale of IC 1101. In blue are the galaxies of the Abell 2029 cluster, captured at the Kitt Peak National Observatory in Arizona, USA, and superimposed in red is the signature of the hot gas envelope that shrouds the cluster, held in place by an enormous quantity of unseen dark matter, and imaged by the Chandra X-Ray Observatory. The elongated core of IC 1101 is visible at the very centre.

GALEX

The Galaxy Evolution Explorer (GALEX) launched in 2003, and performed the first space UV sky survey. Weighing just 280 kilograms (617 pounds), this small orbiting telescope was designed to capture images of galaxies near, and far, and to determine their size, distance and rate of star formation. The images captured ranged from all-sky to ultra deep and revealed nearby giants, as well as distant galaxies over 10 billion years old.

The extremely sensitive ultraviolet detectors on board can capture the emissions of even the youngest, hottest stars, allowing GALEX to map the size of galaxies in unprecedented detail. By probing at the outer edges of galaxies for hidden material, the explorer has provided more accurate measurements of existing galaxies, and revealed the largest spiral galaxy to date, NGC 6872.



Solar cells
300 watts of power were supplied to the craft by gallium-arsenide solar panels, measuring 2.8m (9.2ft) across.

Facing away
The instruments on board were too sensitive to face bright UV sources, like the Earth, the Sun, or any of the stars visible from the ground.

Ritchey-Chrétien telescope
At the heart of GALEX is a 50cm (20in) ultraviolet telescope with a 1.2-degree-wide field of view.

Compact design
At launch, the solar panels were wrapped around the explorer, allowing it to fit on the end of the Pegasus launch vehicle.

Star tracker
The direction of the telescope was determined by a star tracker in combination with a Sun detector, allowing it to focus in on a single area of the sky without damaging the sensors.

Detectors
GALEX contains two detectors within its shell, covering the far and near ends of the ultraviolet spectrum.

© NASA; Kitt Peak; Chandra; Adrian Mann; [illegible] Caltech; DSS; UCL A.Lewis; STScI

Cold Atom Space Lab

Two years from now, NASA will launch an experiment module to the International Space Station that will become the coldest place we know of in the universe

In 2016, NASA is launching a very cool experiment to the International Space Station – literally. Space is really big and incredibly cold: the background temperature of gas and dust floating around in between the stars is three degrees Kelvin (that's -270 degrees Celsius/-454 degrees Fahrenheit). This is just a fraction above absolute zero, the lowest possible temperature, where there is no heat. You would think this was cold enough for anyone but NASA intends to go further by creating the coldest place in the known universe: the Cold Atom Laboratory.

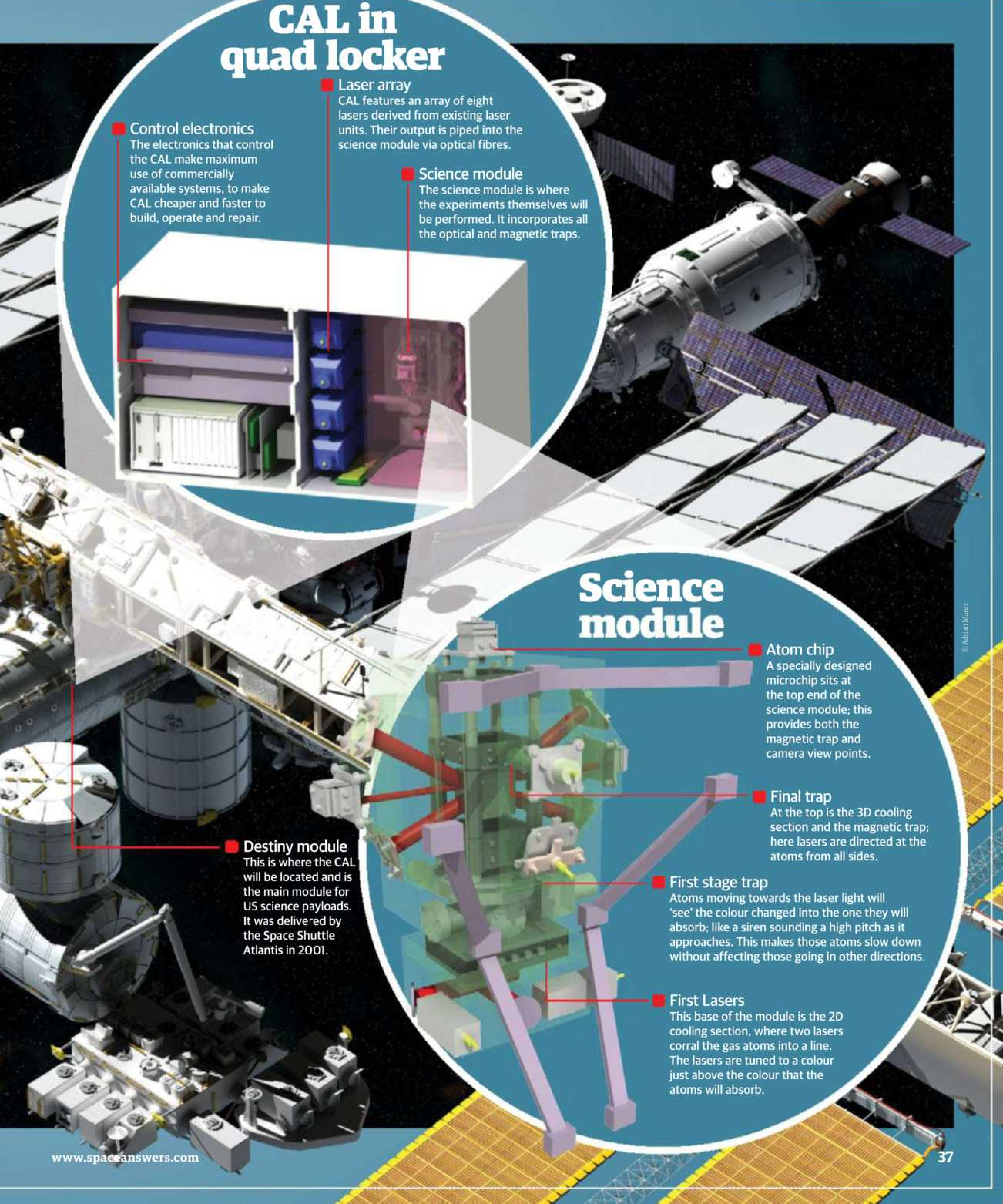
The Cold Atom Lab (CAL) is a very clever piece of equipment built by NASA's Jet Propulsion Laboratory in California. In it, tiny traces of gaseous rubidium or potassium will be captured by lasers, diced up by radio knives and finally set free by magnets to reach 100pK (that is only 0.00000000001 degrees above absolute zero). But why do we want to do this, how do we go about it and why do it in space?

When stuff gets this cold strange things start to happen, quantum things; quantum mechanics is the science of how anything interacts on the scale of atoms and below. Light and matter can behave like particles or waves, and when tiny quantities of gases are cooled so much they can collapse together into one single 'wave' of matter. This is called a Bose-Einstein Condensate (BEC) as it was first proposed by Satyendra Bose and Albert Einstein in 1924, but was not successfully produced until 1995. These BECs open up all sorts of possibilities for studies into the nature of the universe, and indeed possibly a range of spin-offs in sensors and electronics. One of the strangest aspects of BECs is that once formed they can be put together; but they don't mix like clouds of gas, instead they interfere like waves. This means two bits of matter in two separate condensates can combine to create nothing!

But how on Earth, let alone in space, do you go about cooling stuff so much? First of all, the few atoms floating around in a vacuum chamber are corralled by laser beams. On an atomic scale temperature relates to particle speed, and by tuning a laser beam just right you can make atoms slow down (and therefore become colder) when the laser shines on them. In the CAL, two lasers facing each other will first squeeze the gas cloud into a line, before surrounding them with more lasers and magnetic fields to trap them in one spot. Once they are trapped there they are zapped with radio waves, this is called the RF knife because the more active atoms will be preferentially accelerated by the radio waves, jumping out of the trap and making those left behind colder still by taking away their excess energy. The final step is to gradually turn off the magnetic field that has been working with the lasers to trap and compress the cloud. As the cloud is slowly allowed to expand it gets colder, this is the same effect that makes an aerosol can become cold when it is sprayed, but on a much smaller scale.

So as our trapped, diced and squeezed cloud is finally let go, its temperature drops past 100pK and the matter collapses into these strange condensates ready for study; but if we can do this already why take a system to the ISS? The answer is gravity – or the lack of it. When these operations are done on Earth the clouds of particles have to be held up against their own weight, which limits the finesse with which the stages can be carried out. By contrast the microgravity environment of the ISS means that all the stages can be gentler, therefore colder and longer lived. On Earth condensates typically last only a second, in the CAL they are expected to last maybe as much as 20 seconds, making them much easier to study. Intriguingly the lack of gravity might also make it possible to build a condensate large enough for the eye to see, a visual manifestation of the strange quantum world at last brought into our own. ■

> "Traces of gases will be captured by lasers, diced up by radio knives and finally set free by magnets"



CAL in quad locker

Control electronics
The electronics that control the CAL make maximum use of commercially available systems, to make CAL cheaper and faster to build, operate and repair.

Laser array
CAL features an array of eight lasers derived from existing laser units. Their output is piped into the science module via optical fibres.

Science module
The science module is where the experiments themselves will be performed. It incorporates all the optical and magnetic traps.

Science module

Atom chip
A specially designed microchip sits at the top end of the science module; this provides both the magnetic trap and camera view points.

Final trap
At the top is the 3D cooling section and the magnetic trap; here lasers are directed at the atoms from all sides.

First stage trap
Atoms moving towards the laser light will 'see' the colour changed into the one they will absorb; like a siren sounding a high pitch as it approaches. This makes those atoms slow down without affecting those going in other directions.

First Lasers
This base of the module is the 2D cooling section, where two lasers corral the gas atoms into a line. The lasers are tuned to a colour just above the colour that the atoms will absorb.

Destiny module
This is where the CAL will be located and is the main module for US science payloads. It was delivered by the Space Shuttle Atlantis in 2001.

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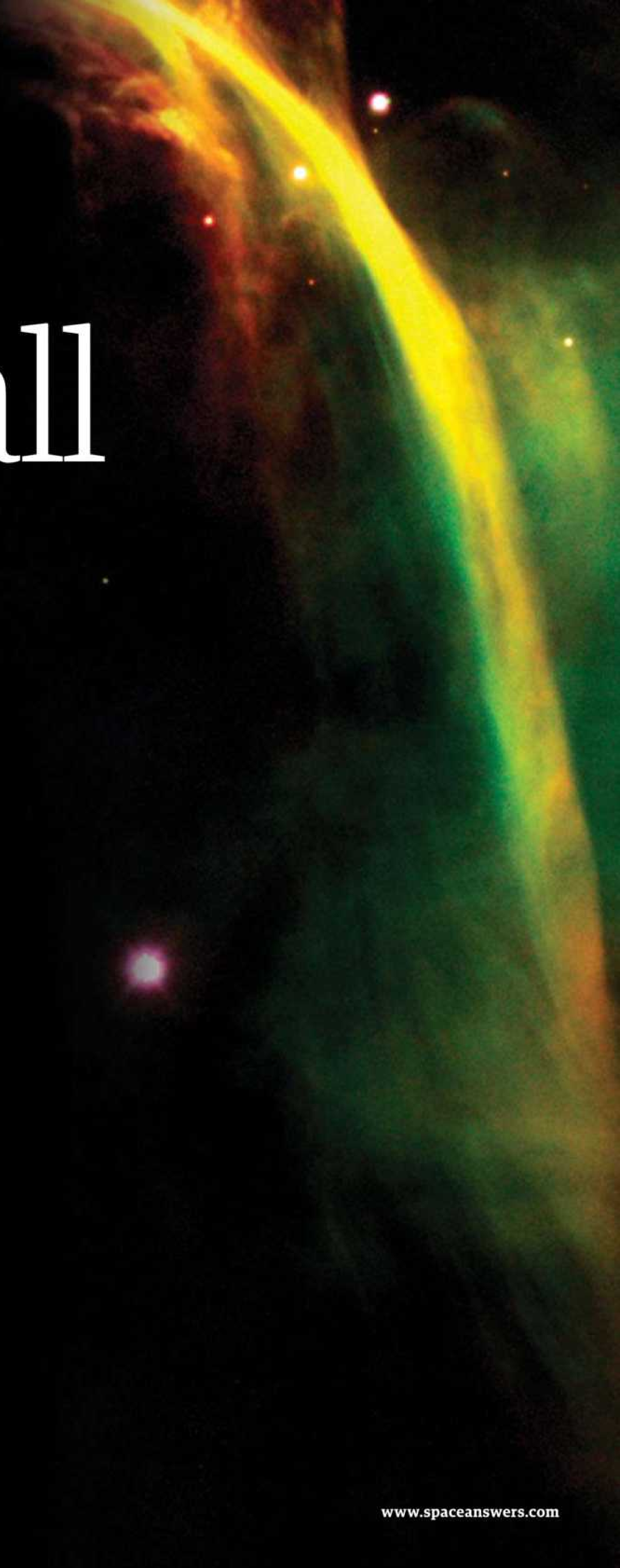
Waterfall Nebula

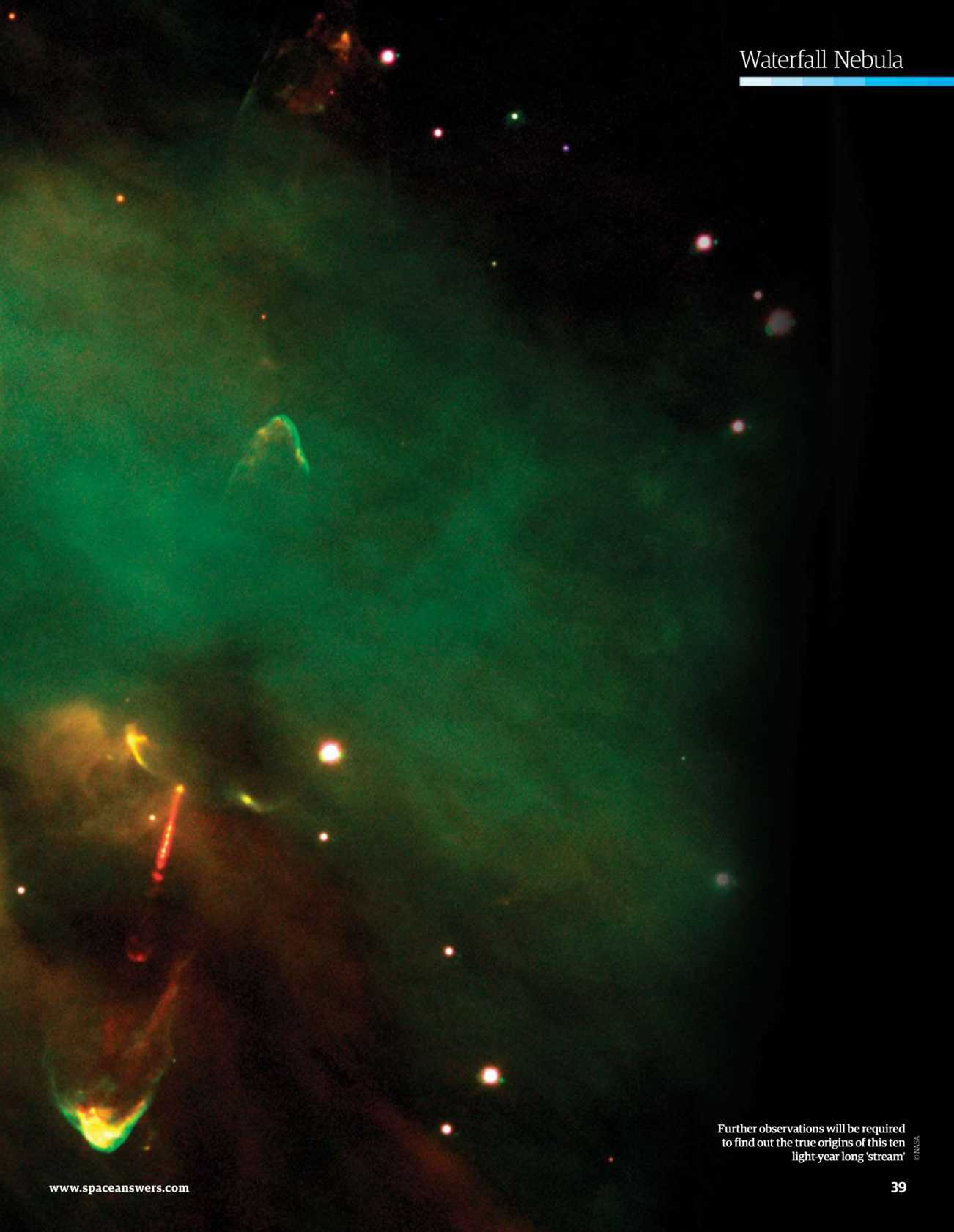
This magnificent structure of mysterious origins bears a striking resemblance to falling water, but for reasons currently unknown



In the Great Orion Molecular Cloud complex 1,500 light years away, can be found one of the most bizarre phenomena ever seen in the universe. Known by its designation Herbig-Haro 222 (HH-222), the Waterfall Nebula is astounding in its shape and has baffled astronomers the world over. The 'stream' extending downwards in this image is about ten light years long and contains an unusual range of colours, possibly due to the interaction of a young star with a molecular cloud.

The most unusual characteristic of this nebula is the concentration of radio sources in its upper left portion. It might be that the origins of the 'stream' are a binary system containing a hot white dwarf, neutron star or black hole, with the waterfall being a jet of radiation emitted from this system. However, our understanding of these binary systems dictates that they should contain a large amount of X-rays. For the Waterfall Nebula this is not the case, so further studies will be needed to truly understand what's going on.

One thing we do know a little about is the red jet that can be seen near the 'base' of the waterfall. Called Herbig-Haro 34 (HH-34), it is thought to be a protostar – a star that has just been born. The brighter areas within it signify regions where matter is slamming together and heating up. The vivid balls of energy within this jet are being ejected from the star at a speed of around 250 kilometres per second (155 miles per second) into the surrounding interstellar dust. The rest of the Waterfall Nebula,



Further observations will be required to find out the true origins of this ten light-year long 'stream'

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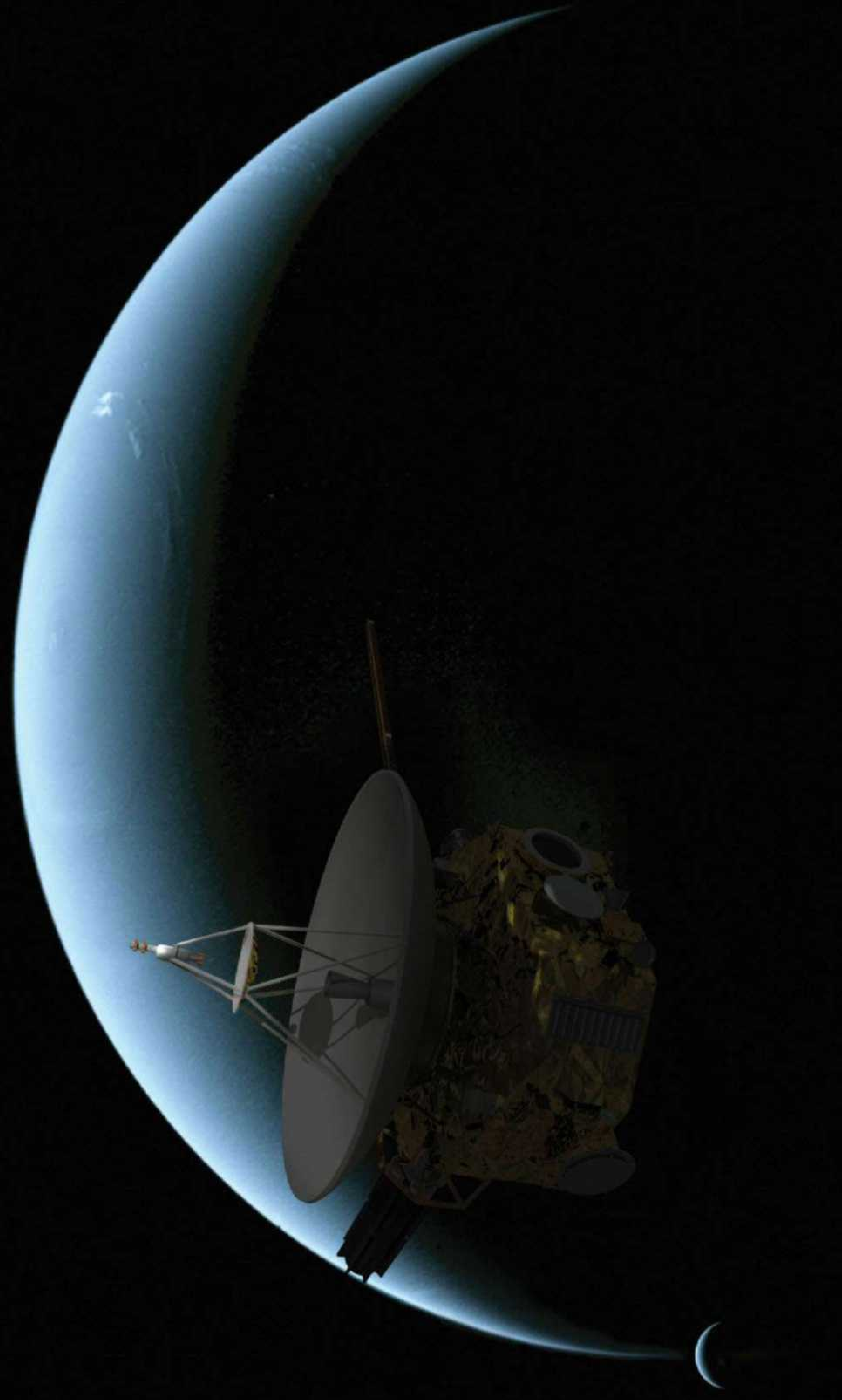


NEPTUNE EXPLORERS

It's now more than 25 years since Voyager 2 became the only spacecraft to visit the planet Neptune. When will we return and what future spacecraft might be used to study this icy blue gas giant?

Written by Jonathan O'Callaghan

On 25 August 1989, the Voyager 2 spacecraft flew by the gas giant Neptune. To date it is the only spacecraft ever to have visited this distant world, but if several teams of scientists get their way it will not be the last.

While all of the planets in the Solar System are unique, Neptune is one of the least understood. The sole Voyager 2 mission to this ice giant, together with observations by telescopes, has gleaned some information about the planet but there is still much to be discovered. And that's why some scientists are clamouring for another mission, be it a flyby akin to the New Horizons mission that will reach Pluto next year or an orbiter like the Cassini spacecraft around Saturn.

Neptune sits about 4.5 billion kilometres (2.8 billion miles) from the Sun and completes an orbit every 165 years. It was first discovered by French mathematician Urbain Le Verrier in 1846. Since then great efforts have been made to further understand what is now classified as the furthest planet from the Sun in our Solar System. With a radius of about 25,000 kilometres (15,000 miles), it is almost four times the size of Earth, while it is 17 times the mass of our world.

In addition, around Neptune is a strange moon known as Triton. Its retrograde orbit - meaning it orbits backwards compared to the other Neptunian moons - has led some to suggest it may be a dwarf planet that was captured from the Kuiper belt in the outer reaches of the Solar System. Triton is thought to be similar in composition and appearance to Pluto; further assessing their similarities may reveal more secrets about small worlds like these.

Perhaps of most interest, however, is Neptune's importance in the search for exoplanets. To date planets like Neptune and Jupiter appear to be very common in our galaxy; understanding more about Neptune could help us learn more about the distant worlds we are so eager to find. It has been suggested that Neptune-types and super-Earths essentially form in the same manner, except Neptune-type planets grow in mass fast enough to capture gas from their young sun, whereas super-Earths do not and instead have a rocky surface. Our own Neptune could reveal information about what we might expect to find as we continue to explore the galaxy.

"We actually know relatively little about the icy giants - Uranus and Neptune - in our Solar System, and this category of planet is very plentiful in our discoveries of exoplanets," Dr Candice Hansen, a senior scientist at the Planetary Science Institute, tells **All About Space**. Dr Hansen was a member of NASA's Voyager flight team at the Jet Propulsion Laboratory (JPL) and, more recently in 2007, proposed a mission to Neptune called Argo. But, as she explains, Triton makes a mission to Neptune more appealing over other candidates like Uranus.

"Triton is a world with an atmosphere composed of nitrogen that freezes out into polar caps seasonally," Dr Hansen says. "At 38 Kelvin [-235 degrees Celsius, -391 degrees Fahrenheit] surface temperature you would expect to find a world literally frozen, yet we see geysers erupting sending plumes of particulates into the thin atmosphere. The surface is, geologically speaking, young, less than 100 million years. Does that mean that there is a liquid layer of water beneath the icy crust?"

It has been suggested that a Flagship Mission to Neptune - NASA's most expensive and science-intensive class of missions - might be possible beyond 2050 after more pressing goals, such as the exploration of Titan and Europa, have been achieved. But that would leave a gap of more than 60 years between missions to the blue giant.

So in 2007 Dr Hansen and a team of scientists proposed the Argo mission, which would fall between Voyager 2 and an orbiter in the 2040s. "Dr Heidi Hammel [of the Space Science Institute] and I were lamenting the fact that there were no missions to Neptune on the drawing board," says Dr Hansen. "It occurred to us that if we proposed a flyby mission rather than an orbiter, we might have a chance of fitting within the New Frontiers [mid-class] programme cost constraints."

But while a flyby mission had not been high on NASA's priorities, as the science return of such a mission over an orbiter had been called into question, Dr Hansen and her team found a 'remarkable trajectory opportunity' that, using gravitational assists at Jupiter and Saturn, would get a spacecraft to Neptune in just ten years.

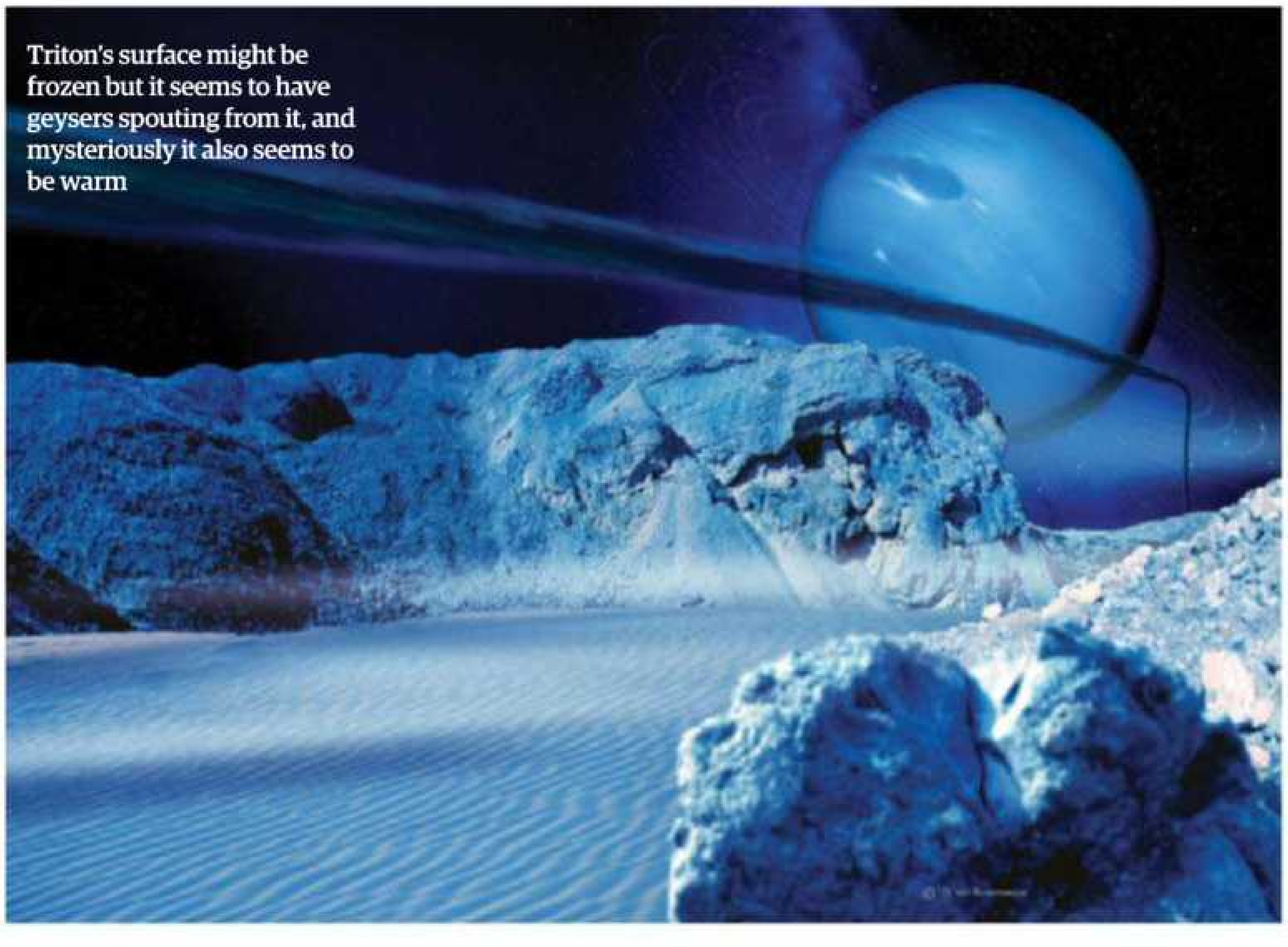
"Our goal was to take advantage of modern instrumentation and our improved understanding of processes in the outer Solar System that has been developed in the 25 years since the Voyager flyby," Dr Hansen continues.

Sadly though, the mission ran into problems when the only present-day power source feasible for such a mission was not available. Argo would have required a nuclear generator using plutonium-238, which at the time was scarce: NASA had deemed the mission impossible without this element, although it has since started new production.

Even worse, the launch window for the specific planetary alignment to make the Argo mission possible closes in 2020 and will not re-open until around 2034, "so unless we were to start designing the spacecraft tomorrow we've missed it," Dr Hansen laments. But she's hopeful that an orbiter might well make it to the planet in the meantime: "It's a fascinating destination!"

And that's where two other teams of scientists come in. Dr Adam Masters, previously of JAXA and now at Imperial College London, is championing one of these teams. He's hoping for a mission to Neptune to not only find out more about Triton but also Neptune's role in the early Solar System.

"A mission to Neptune is desirable because it's a unique planetary system that holds the answers to many questions about how the Solar System came to be in its present state, because of the important role Neptune played in its early history," he explains. Like Dr Hansen, he adds how Neptune's similarity to planets found outside the Solar System could also be

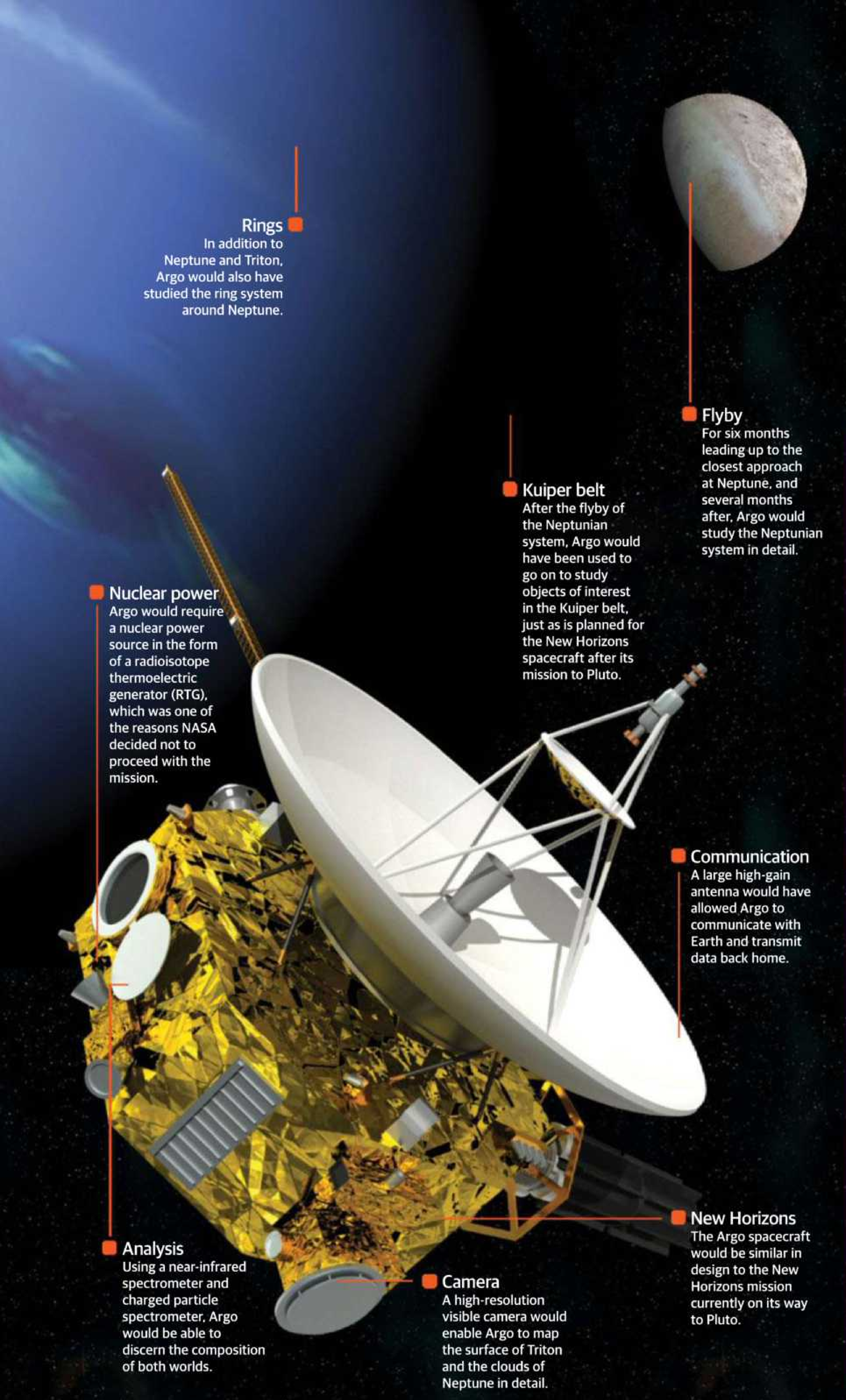

Triton's surface might be frozen but it seems to have geysers spouting from it, and mysteriously it also seems to be warm

The flyby mission

How the Argo spacecraft would study Neptune and Triton

Journey
If it were launched before 2020 it would take Argo about ten years to get to Neptune, using favourable alignments of Jupiter and Saturn as gravitational assists.

> "A mission to Neptune is desirable because it's a unique planetary system"
>
> **Dr Adam Masters**



Rings
In addition to Neptune and Triton, Argo would also have studied the ring system around Neptune.

Flyby
For six months leading up to the closest approach at Neptune, and several months after, Argo would study the Neptunian system in detail.

Kuiper belt
After the flyby of the Neptunian system, Argo would have been used to go on to study objects of interest in the Kuiper belt, just as is planned for the New Horizons spacecraft after its mission to Pluto.

Nuclear power
Argo would require a nuclear power source in the form of a radioisotope thermoelectric generator (RTG), which was one of the reasons NASA decided not to proceed with the mission.

Communication
A large high-gain antenna would have allowed Argo to communicate with Earth and transmit data back home.

New Horizons
The Argo spacecraft would be similar in design to the New Horizons mission currently on its way to Pluto.

Analysis
Using a near-infrared spectrometer and charged particle spectrometer, Argo would be able to discern the composition of both worlds.

Camera
A high-resolution visible camera would enable Argo to map the surface of Triton and the clouds of Neptune in detail.

Did you know?

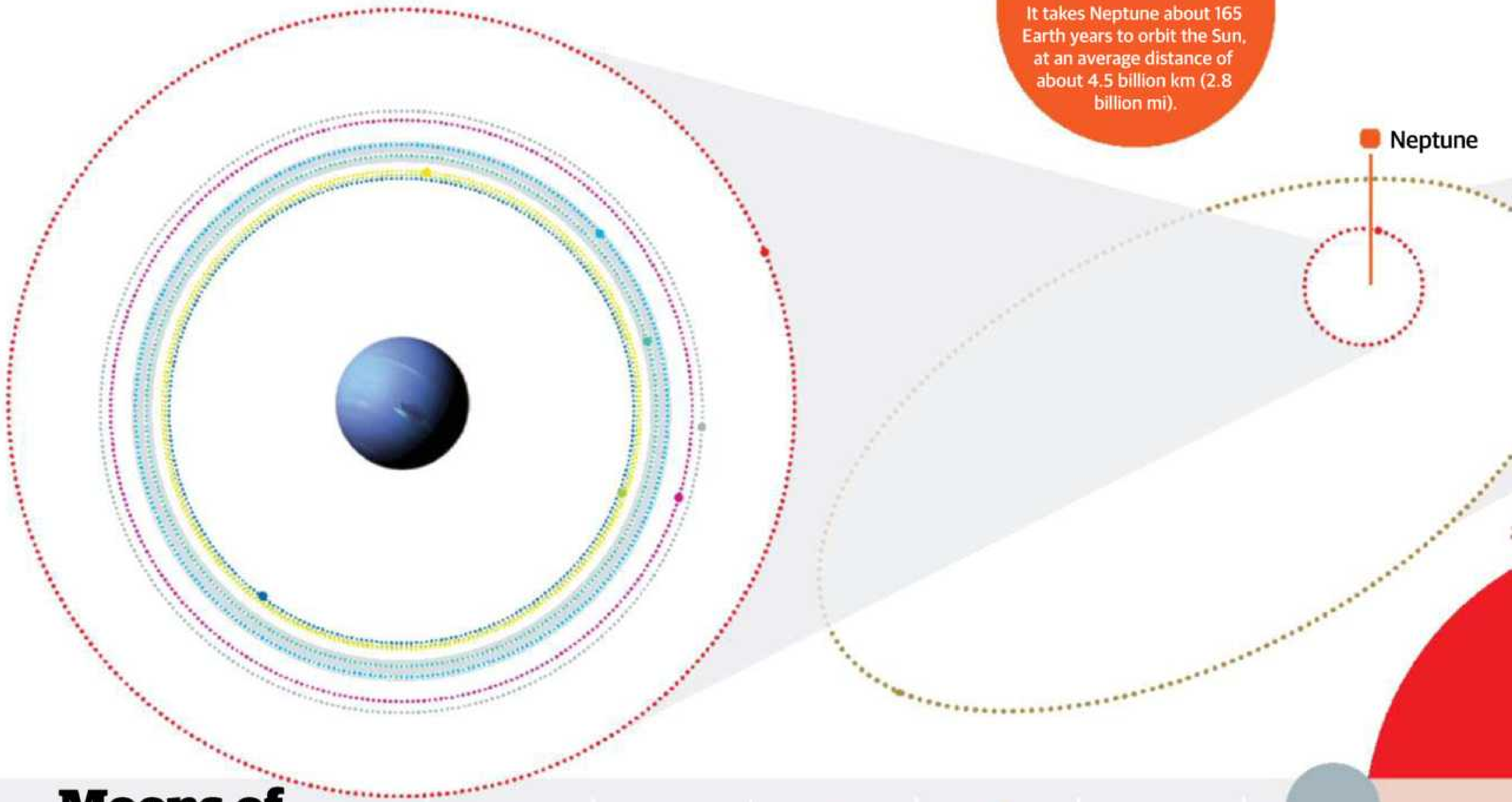
The winds on Neptune are among the strongest in the Solar System, nine times stronger than winds on the Earth.

Who was Urbain Le Verrier?

Born on 11 March 1811 in Saint-Lô, France, Urbain Jean-Joseph Le Verrier grew to become a respected French astronomer. In 1845, he used mathematical calculations to predict the position and orbit of a large outer planet in the Solar System. Previous attempts to find such a world had proven unsuccessful or gone unnoticed, as evidenced by Galileo, who spotted Neptune in 1612 but merely regarded it as a star. Le Verrier, however, asked an astronomer to confirm his findings and found the planet to be just one degree from where it was predicted to be, making Neptune the only planet in the Solar System to be found through a mathematical prediction. Among many awards Le Verrier was given the Copley Medal from the Royal Society of London for the discovery. Le Verrier wasn't always right, though; he later predicted the existence of an asteroid belt or a planet called Vulcan between Mercury and the Sun, which was eventually proved to be incorrect.

The Neptunian system

Why is this ice giant and its moons so interesting?



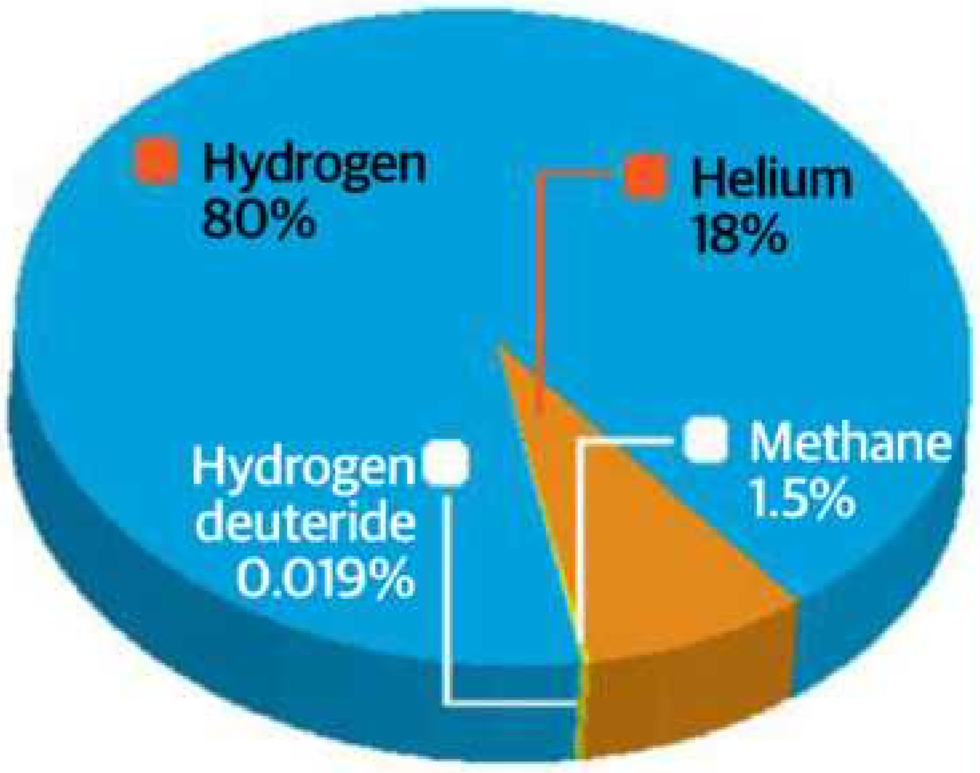
Did you know?

It takes Neptune about 165 Earth years to orbit the Sun, at an average distance of about 4.5 billion km (2.8 billion mi).

Moons of Neptune

	Naiad	Thalassa	Despina	Galatea	Larissa	S/2004 N1	Proteus
	●	●	●	●	●	●	●
Diameter	66km (41mi)	82 km (51mi)	150km (93mi)	176km (109mi)	194km (121mi)	18km (11mi)	420km (261mi)
Distance from Neptune	48,227km (29,967mi)	50,074km (31,115mi)	52,526km (32,638mi)	61,953km (38,496mi)	73,548km (45,701mi)	105,283km (65,420mi)	117,646km (73,102mi)

Neptune's atmosphere



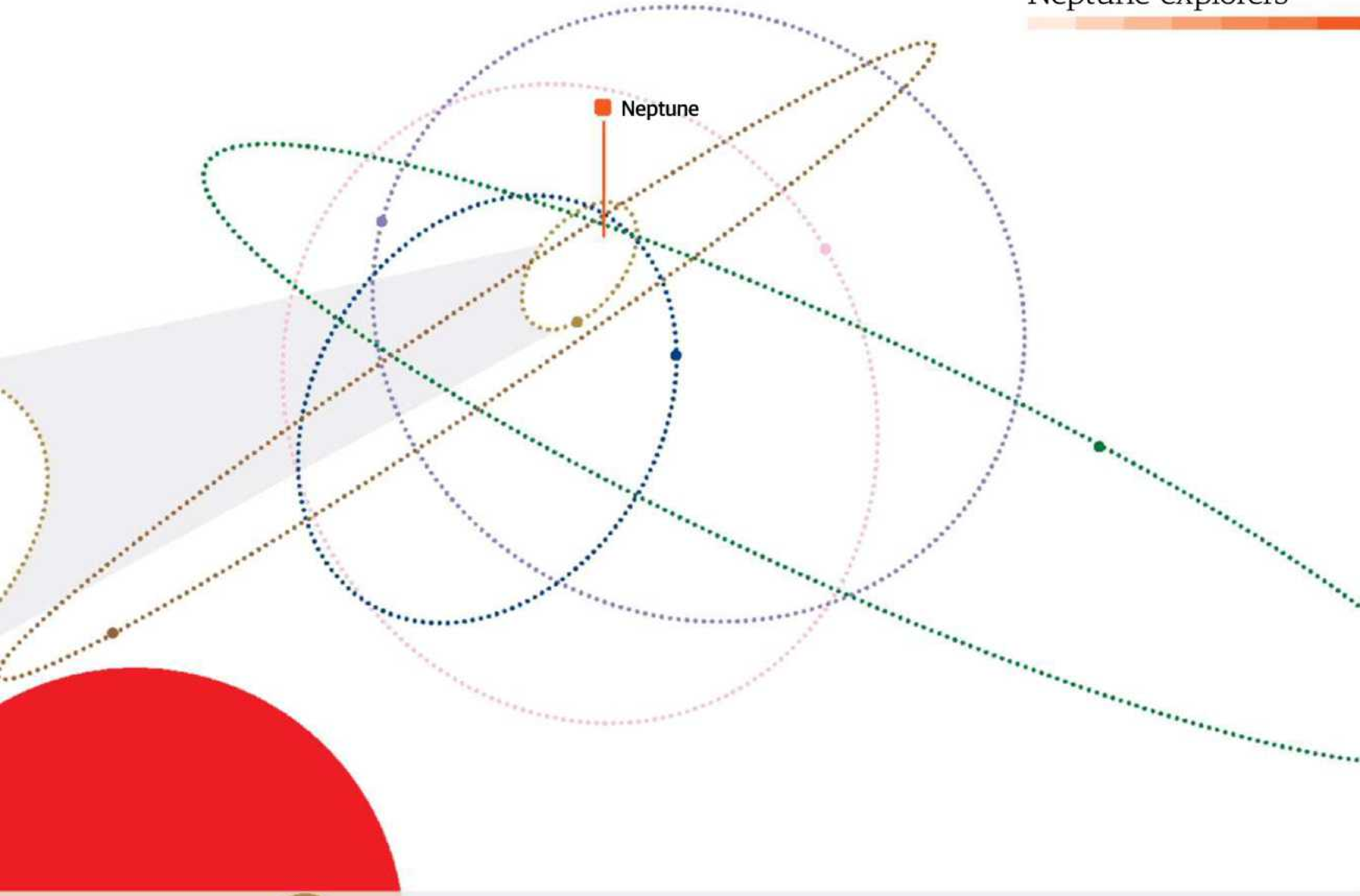
of importance, while Triton bears similarities to an object hailing from the Kuiper belt.

His proposal is for an orbiter to examine both Neptune and its moon Triton. "I'd most like to understand why Neptune's atmosphere is the most meteorologically active in the Solar System, despite its great distance from the Sun. Also, to know whether Triton is geologically active and if it has a subsurface ocean," he says.

Their proposal was recently submitted to the European Space Agency's Cosmic Vision programme as a candidate for one of its next two large L-class missions, which will cost in the region of £800 million ($1.3 billion). "Because of the success of past and present spacecraft missions to Jupiter and Saturn, we are now in a position to start seriously talking about a mission to the outermost planet," he continues. "Our Neptune orbiter mission concept is similar to previous mission architectures studied by colleagues in the United States in the past, but this was the first time such an idea had been put on the European table."

Their unnamed mission would involve launching off one of the most powerful rockets around today, followed by a 15-year-long cruise to Neptune, with a gravity assist from Jupiter on the way. Once captured by Neptune's gravity they would spend at least two years orbiting the planet, making 55 flybys of Triton in the process. It would use chemical and solar electric propulsion, with electric power being provided by nuclear power cells. On board would be a variety of instruments for remote sensing and in situ measurements, allowing a number of questions to be answered, including what Neptune's interior is like, how its magnetic field works, what processes are taking place on Triton's surface and more.

The mission would rely on tried-and-tested technology, using instruments that have been employed on deep-space probes before. But while the technology might not be too much of a challenge,



	Triton	Nereid	Halimede	Sao	Laomedeia	Psamathe	Neso
Diameter	2,707km (1,682mi)	340km (211mi)	62km (39mi)	44km (27mi)	42km (26mi)	40km (25mi)	60km (37mi)
Distance from Neptune	354,759km (220,437mi)	5,513,818km (3,426,128mi)	16,611,000km (10,321,597mi)	22,228,000km (13,811,839mi)	23,537,000km (14,643,855mi)	48,096,000km (29,885,469mi)	49,285,000km (30,624,279mi)

actually getting a spacecraft into orbit around Neptune is fairly difficult. Two options are available: using what is known as a Hohmann transfer orbit to gradually match the orbit of Neptune and move into position, or a more direct approach using gravitational assists from other planets and then slowing down once at Neptune.

"Putting a spacecraft into orbit around any planet isn't easy!" continues Dr Masters. "However, we've had a lot of success in the past, and there's no reason why we can't be successful again at Neptune in the future. Perhaps the most annoying thing about a mission to Neptune is that we would have to wait 15 years from the launch before we arrive and start making discoveries, but I think those discoveries would definitely be worth the wait."

One thing that will also be needed to make a Neptune orbiter a possibility will be an extension of the Deep Space Network (DSN). This worldwide network of large antennas and communications facilities is used to send and receive data from interplanetary spacecraft. But for an extended mission at Neptune, it would need to be improved so that all the information gathered by the orbiting spacecraft could make it back to Earth.

"We were discussing which of the two icy giants to investigate first... we asked ourselves, why not explore both?"

Dr Masters' proposal isn't the only concept for a mission to Neptune being considered by ESA, though. Another called ODINUS (Origins, Dynamics and Interiors of Neptunian and Uranian Systems), led by Dr Diego Turrini from the Institute for Space Astrophysics and Planetology, is also in the works.

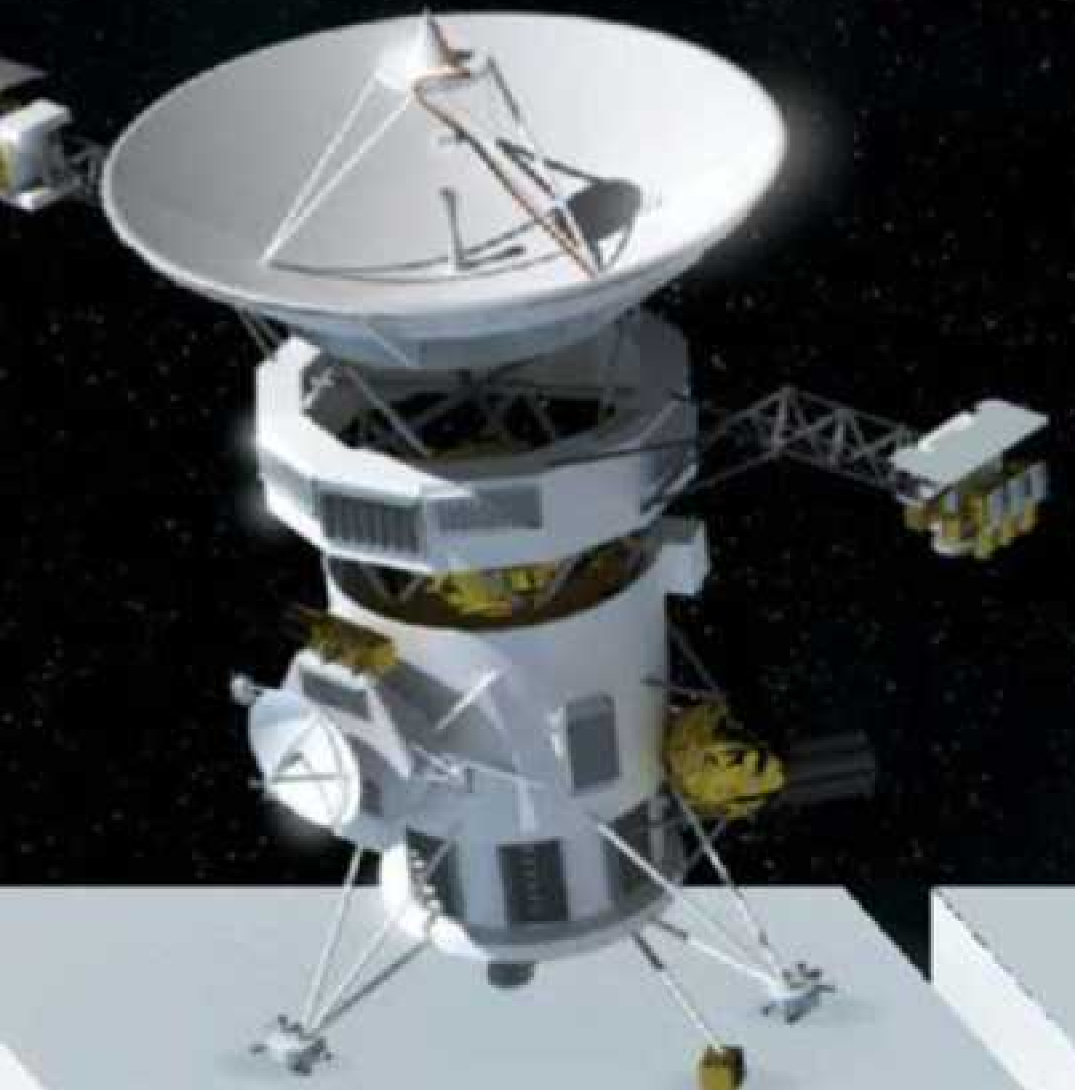
ODINUS would consist of two twin spacecraft, similar to Voyager 1 and 2, sent on missions to orbit Neptune and Uranus. Named Freyr and Freyja, the latter would be placed in orbit of Neptune, possibly separating from its partner once they had both reached Uranus together. Both would carry an advanced suite of instruments to study in detail the planets they were sent towards.

"ODINUS was born during a coffee break from a discussion between me and the second author of the ODINUS proposal, Romolo Politi," Dr Turrini says. "We were discussing about which of the two icy giants would be the most interesting to investigate first with a space mission and at a certain point we asked ourselves, mostly joking, why not explore both."

The orbiters

How these missions would study the Neptunian system for years to come

Did you know?
It's thought that Neptune has an Earth-sized solid core that is surrounded by water and other melted ices.

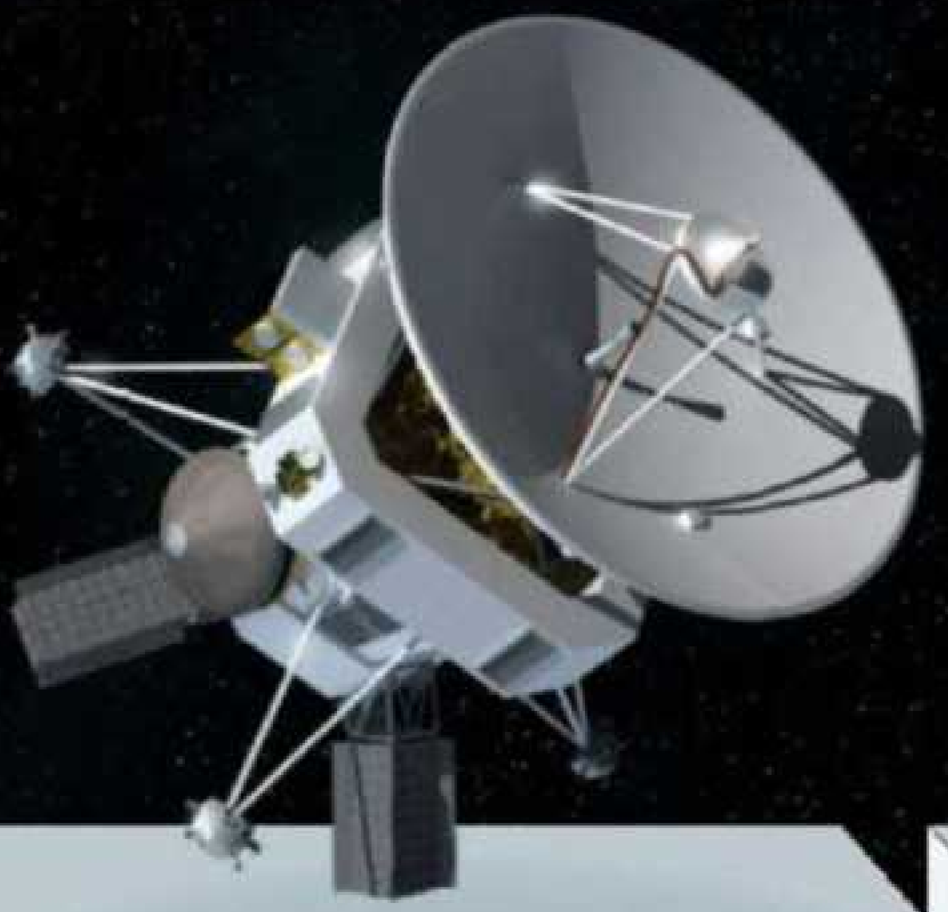


Freyr

Target: Uranus
Launch date: 2025
Propulsion: Nuclear/Solar
Power: Radioisotope thermoelectric generator (RTG)

Mission objectives:

The first of the twin spacecraft would take 13 years to reach the first of the ice giants, Uranus. Here it would study the interior and dynamics of the planet in an effort to further our understanding of the Solar System and how it evolved. By the time ODINUS's launch date arrives, we should have a more sound understanding of the Solar System's origins, through missions like Rosetta.

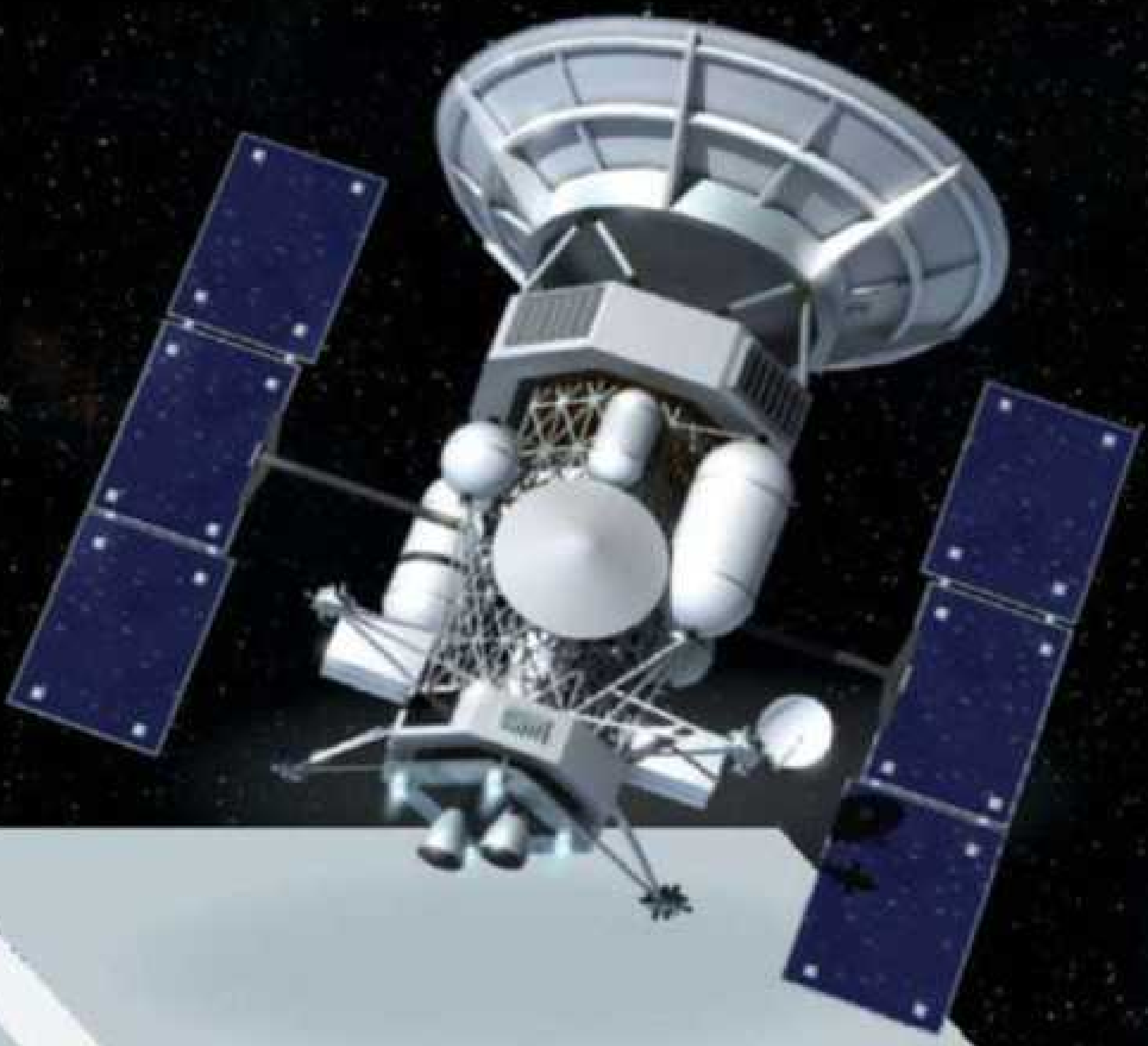


Freyja

Target: Neptune
Launch date: 2025
Propulsion: Nuclear/Solar
Power: RTG

Mission objectives:

The second ODINUS craft will be travelling that much further than its twin, around 4.5 billion kilometres (2.8 billion miles) to Neptune, which will take the spacecraft a total of 16 years to get to. Its objectives will be similar to ODINUS 1 - exploring the interior, magnetosphere and atmosphere of Neptune - except it will also investigate the more interesting natural satellite of Neptune, Triton.



Unnamed Neptune orbiter

Target: Neptune
Launch date: TBC
Propulsion: Chemical/Solar
Power: RTG

Mission objectives:

Dr Adam Masters' proposal will investigate Neptune's atmosphere and aims to discover why it is so meteorologically active, despite being so far away from the Sun. A contender for one of ESA's future L-class missions, it will spend two years in orbit around Neptune and make dozens of flybys of Triton. It aims to establish what processes take place on Triton's surface, among other objectives.

Such a twin spacecraft method is not unprecedented; of course, the Voyager probes are perhaps the most famous, but ESA also carried out its own twin mission of sorts with the Mars Express and Venus Express spacecraft, which launched in 2003 and 2005 respectively. "Then we 'only' had to decide which measurements to prioritise [for ODINUS] and which ones instead to sacrifice in order to design a mission that was scientifically sound and technologically feasible," Dr Turrini continues.

The endeavour would fall to a single L-class ESA mission. The favoured scenario for the mission is that the two spacecraft would launch together on an Ariane V rocket. A third stage using solar electric propulsion would take them to the orbit of Jupiter. The first spacecraft would then reach Uranus 13 years after launching and the second would reach Neptune three years later.

At Neptune the spacecraft would enter its orbit at the boundary of the region populated by the outermost moons. Using encounters with the satellites, it would then spiral inwards towards the planet in a mission lasting about three years. The timing of the mission would also mean that the operation of the two spacecraft would not overlap, so managing the spacecraft would not be a problem.

Dr Turrini admits, however, that such an approach is challenging. "Aside from the obvious difficulty of fitting this ambitious mission into the budget of a single L-class mission, there are also technological issues to overcome," he says. These are the transmission of data from Neptune; the necessity for nuclear power at the orbit of Neptune; and finally the long cruise phase, which increases the cost of the mission and the risk that the spacecraft may not survive the journey.

But Dr Turrini is hopeful that such a mission, be it ODINUS or another proposal to Neptune, is not out of the question. Indeed, it appears that ESA is generally in favour of a mission to Neptune, while NASA is warming to the idea after it has completed the exploration of other worlds that are higher on the scientific agenda, namely Europa and Titan. "In the words of ESA, exploring these planets is 'a timely milestone, fully appropriate for an L-class mission'," says Dr Turrini. "Going back to Uranus and Neptune is also among the priority goals of NASA, which already performed dedicated feasibility studies. I think the time for such a mission is approaching, but whether it will be possible for me to see it fly, or [whether] it will be something for my students to spend their careers on, is a different matter."

Whatever the outcome of these proposals, it seems that a return to Neptune in the next few decades might not just be a pipe-dream, but instead an inevitability. One only needs to look at the success of existing orbiters in the Solar System, such as Cassini around Saturn, to see that such an ambitious mission is possible. Neptune, though, poses an entirely new challenge, but as evidenced by these various teams of scientists there are no shortage of proposals for spacecraft to make the journey to the edge of the Solar System.

And perhaps it is fitting that, 25 years after Voyager 2 became the first and only spacecraft to visit Neptune so far, scientists can once again dream of visiting this distant planet. If they get their way, it will not be the same fleeting visit experienced by Voyager 2; instead, an advanced probe could spend years in orbit, returning untold scientific observations of this fascinating gas giant and its equally enthralling moon Triton. ■

ESA's Jupiter Icy Moon Explorer (JUICE) mission will explore Jupiter and its moons when it arrives in 2030

ESA's Cosmic Vision

ESA's Cosmic Vision is a programme to select missions from 2015 to 2025 that will answer key questions about the Solar System and the universe. The mission will seek to address how planets and life form, how the Solar System works, what the fundamental physical laws of the universe are and how the universe originated.

The missions are split into three classes: small (S), medium (M) and large (L). S-class missions have a budget up to £40 million ($65 million), with the first selected mission being CHEOPS, a satellite that will hunt for exoplanets beginning in 2017. M-class missions include Euclid, a mission that will study dark energy and dark matter from 2020.

The L-class missions have a budget of up to £800 million ($1.3 billion). So far two have been selected: JUICE, a mission to Jupiter that will launch in 2022, and ATHENA, an X-ray observatory that will launch in 2028. It's hoped that the final L3 slot for a large mission might go to one of the proposals to explore Neptune.

The only mission to Neptune

Dr William Kurth, co-investigator on the Voyager Plasma Wave Science investigation, on Voyager 2 and what the future holds

Why was the Voyager 2 mission to Neptune so important?

"Voyager filled in what could be considered a blank slate of what we knew about Neptune. Earth-based images of Neptune were little more than points of light at that time. Hence, Voyager showed us the nature of Neptune's atmosphere, its great dark spot and a first reconnaissance of its system of moons and rings. Triton turned out to be a surprise in that Voyager found evidence of current geologic activity with the discovery of plumes. In NASA's strategy of planetary exploration, Voyager 2 represented the reconnaissance phase - a first flyby to assess the territory and to formulate the questions that a return mission would want to answer."

Was it always planned that the spacecraft would fly by Neptune?

"Before the Mariner Jupiter-Saturn 1977 (now called Voyager) mission began, a mission called the Grand Tour was studied. The Grand Tour would take advantage of a planetary alignment of the outer planets that only occurs about once ever 176 years to use gravitational assists to get from one planet to the next (Jupiter, Saturn, Uranus and Neptune) in about 12 years. However, in the early Seventies, NASA was young and no one knew you could build a spacecraft that would survive more than a decade to complete such a mission. And, to attempt to do so would be very expensive. So the Jupiter-Saturn mission was proposed as a more affordable replacement. The engineers, though, were instructed to do nothing that would prevent the spacecraft from continuing on to Uranus and Neptune, should they survive.

"It was thought that a close flyby of Titan at Saturn was very important given its dense nitrogen atmosphere, and executing that trajectory with Voyager 1 meant that the appropriate gravity assist to Uranus and the Titan flyby could not both be done. This is why only Voyager 2 completed the Grand Tour."

What do you expect from future missions to Neptune?

"I would expect the next mission to Neptune to be similar in many respects to the Galileo mission to Jupiter or the Cassini-Huygens mission to Saturn. Cassini-Huygens was designed to study Saturn as a system, including the planet, moons, rings, and magnetosphere. I would hope that the next Neptune mission would have objectives to study those same aspects of Neptune's system from the vantage point of an orbiting spacecraft with perhaps an atmospheric probe of Neptune or maybe a lander for Triton, should such a mission be affordable."

Will there be another mission to Neptune in the near future?

"I would hope that mankind will see the importance of continuing its exploration of the outer planets with missions such as one to Neptune."

> "Voyager found evidence of current geologic activity"

5 REASONS TO GO TO NEPTUNE

Why exploring the blue icy gas giant is so important

1 To find out how the Solar System began

It's thought that Neptune may have played a key role in the early Solar System, dictating the orbits and ultimately the structure of certain objects and regions in the outer Solar System such as Pluto and the Kuiper belt.

2 It's similar to exoplanets

To date many of the exoplanets that have been found appear to be similar to Neptune in size. This means that understanding more about Neptune could reveal more about exoplanets in distant planetary systems.

3 To understand its atmosphere

Neptune's atmospheric dynamics, namely its exceptionally strong winds and short-lived storms, are almost unique in the Solar System. Its winds also sometimes move in opposite directions to its rotation, something not seen on Jupiter and Saturn.

Clouds on Neptune indicate a vast and complex atmosphere, with winds stronger than anything else seen on planets in the Solar System

4 To learn more about Triton

Triton is one of the most fascinating worlds in the Solar System. It appears to be a captured dwarf planet with a nitrogen atmosphere that freezes, while geysers erupt from its surface. A Neptune mission could discover if there is water beneath its surface.

5 To study its magnetic field

Neptune has a bizarre magnetic field that is tilted 47 degrees from the planet's rotation. As the planet rotates in the solar wind its magnetosphere undergoes dramatic changes. The tilt means Neptune's auroras appear over wide areas of the planet, unlike on Earth where they are mostly at the poles.

Triton is Neptune's most intriguing moon. It is thought to possibly be a dwarf planet captured from the Kuiper belt

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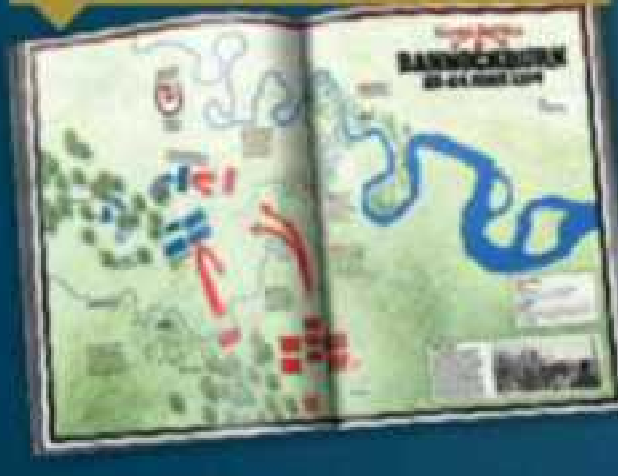

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The secret spaceplane

The supersonic spaceplane on a top secret mission

In 1999, NASA commissioned Boeing to build a miniature, unmanned version of the Space Shuttle. Five years later, the project was handed over to the United States military and it suddenly became a lot more secretive.

The initial plan behind the X-37 project was to create a spaceplane that was much lighter and smaller than the Space Shuttle so it could be launched quickly and cheaply. On the surface, nothing has really changed as the spaceplane is still pretty much the same machine - an 8.8-metre (29-foot) by 2.9-metre (9.5-foot) spacecraft with a launch weight of just 4,990 kilograms (11,000 pounds).

However, it is the under-the-radar nature of the launches that has got tongues wagging. The project was again transferred in 2006, this time to the Air Force's Rapid Capabilities Office, which is tasked with developing combat support and weapon systems. Many commentators are wondering whether the US military is planning on using the unmanned plane as tool for disrupting enemy satellites. None of the three missions flown so far - launched in 2010, 2011 and 2012 - have had their payloads revealed. The only information released is that the payload is classified and that the primary mission has not changed. According to official spokespeople, X-37B is still being launched to test new technology and gather data on how small spaceplanes hold up in orbit.

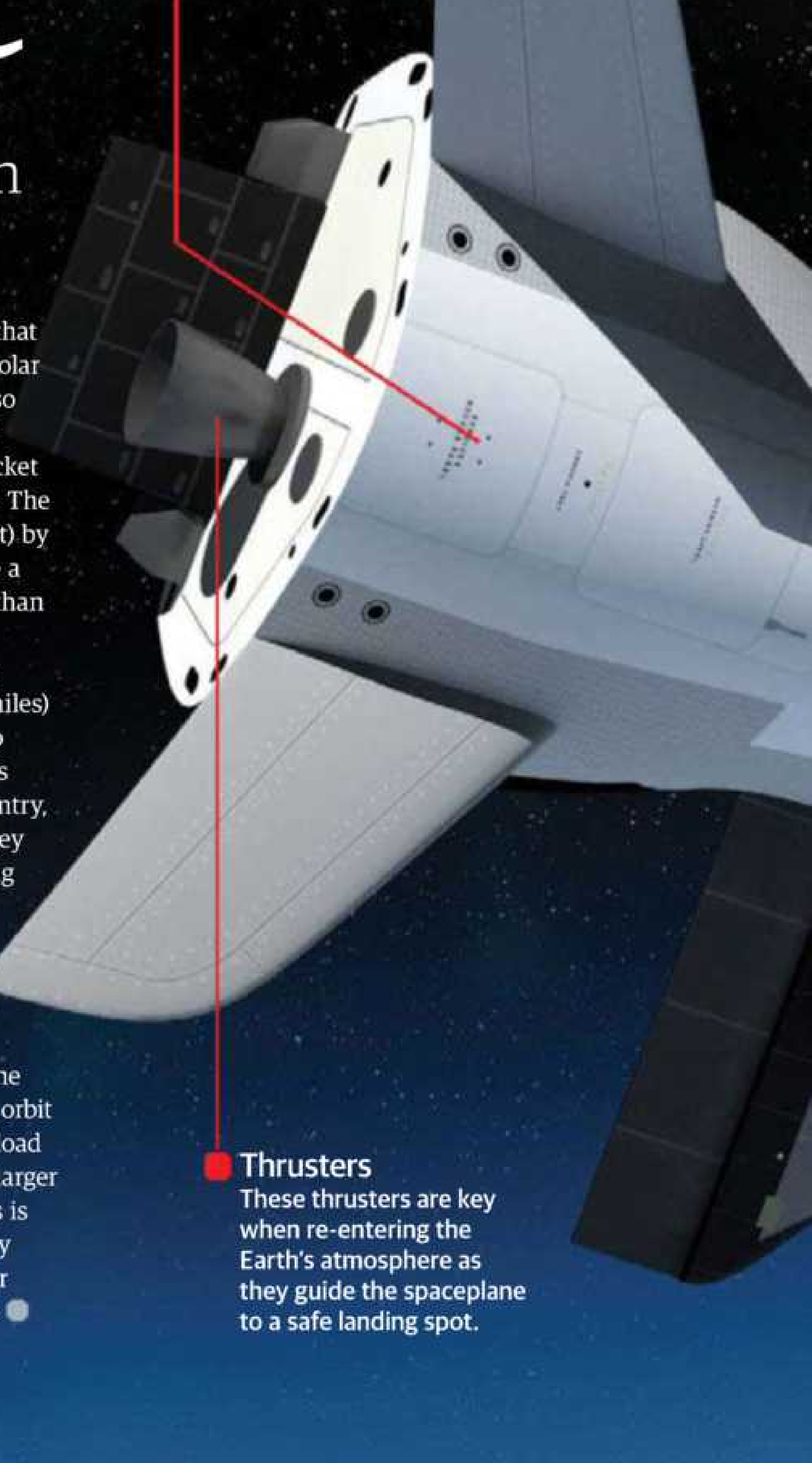
Among the difficulties of turning this research project into a weapon are the lack of manoeuvrability and the fact that it needs a runway to land, making it vulnerable to attacks.

The spaceplane is an extremely interesting piece of technology, even without the mystery that surrounds what it is being used for. It runs off solar power and an Aerojet AR2-3 engine. There is also a hydrogen peroxide tank in the rear to provide thrust once it has detached from the Atlas V rocket that launches it from Cape Canaveral in Florida. The payload bay measures just 2.1 metres (seven feet) by 1.2 metres (four feet), so even if it were to house a weapon, it would have to be only a little larger than a motorbike.

In orbit, the X-37B is able to travel at up to an incredible Mach 25 - that's 8.5 kilometres (5.3 miles) a second! It will provide valuable information to researchers regarding the ability of the materials used to withstand the pressure and heat of re-entry, as the reusability of the spaceplane is another key target for NASA. The X-37B is capable of reaching altitudes of 805 kilometres (500 miles).

Having flown three successful missions, as well as many lower altitude tests, it is hoped that the X-37B will be a useful, low-cost way of ferrying astronauts, or at least essential supplies and equipment, into space. The unmanned nature of the plane makes it able to orbit for many months at a time without needing to load it with food, water and other essentials that its larger cousins required. Working on the basis that this is not a not-so-secret weapon, the X-37B could very easily become an important, reusable tool in our trips to and from outer space in the near future.

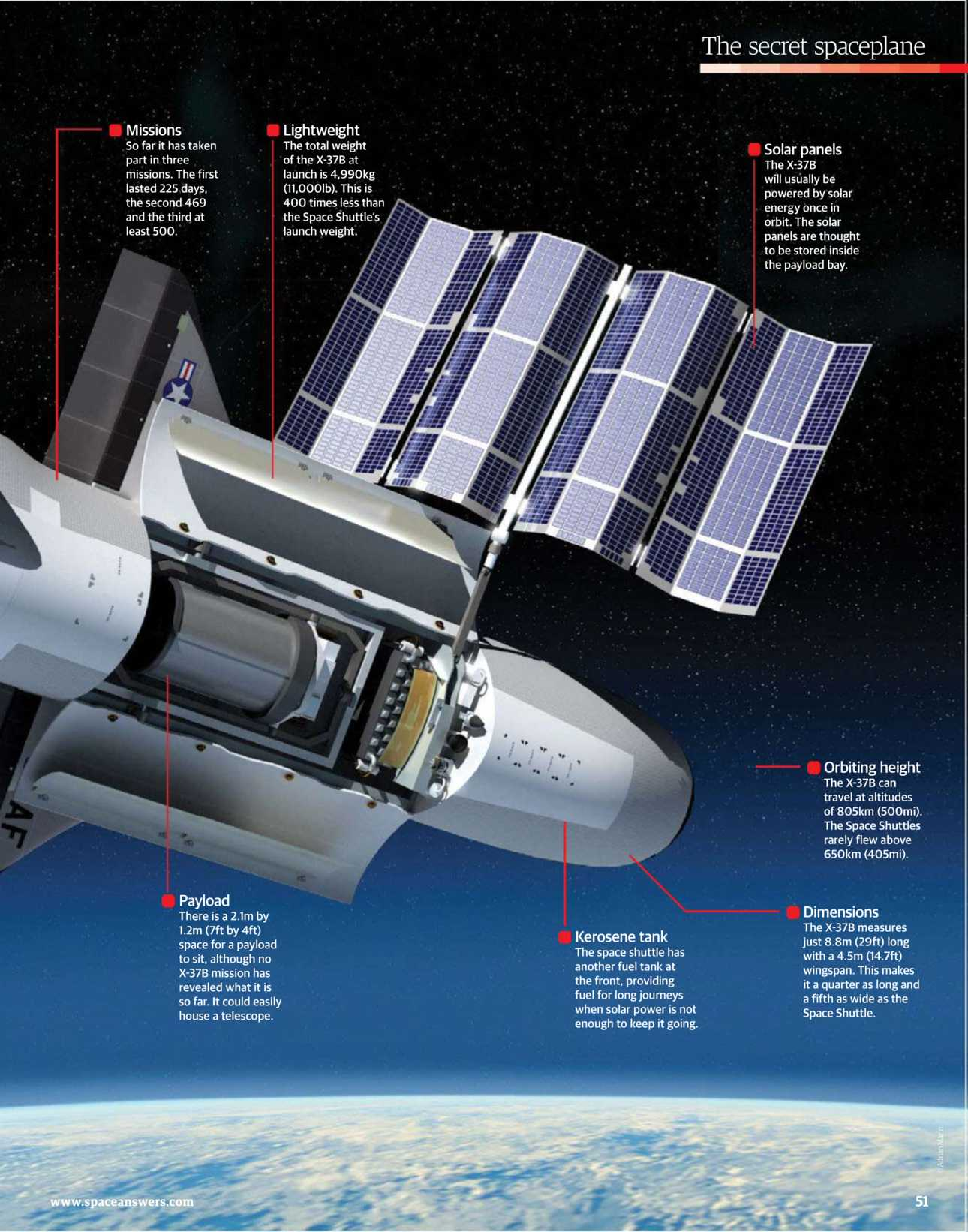
> "In orbit, the X-37B is able to travel at up to an incredible Mach 25 - that's 8.5 kilometres (5.3 miles) a second"



Hydrogen peroxide tank
The hydrogen peroxide tank in the rear of the spaceplane is used as a propellant to provide thrust when needed.

Thrusters
These thrusters are key when re-entering the Earth's atmosphere as they guide the spaceplane to a safe landing spot.

Launch
Launched from Florida's Cape Canaveral, the X-37B is released from an Atlas V rocket before entering orbit around the Earth.



Missions
So far it has taken part in three missions. The first lasted 225 days, the second 469 and the third at least 500.

Lightweight
The total weight of the X-37B at launch is 4,990kg (11,000lb). This is 400 times less than the Space Shuttle's launch weight.

Solar panels
The X-37B will usually be powered by solar energy once in orbit. The solar panels are thought to be stored inside the payload bay.

Payload
There is a 2.1m by 1.2m (7ft by 4ft) space for a payload to sit, although no X-37B mission has revealed what it is so far. It could easily house a telescope.

Kerosene tank
The space shuttle has another fuel tank at the front, providing fuel for long journeys when solar power is not enough to keep it going.

Orbiting height
The X-37B can travel at altitudes of 805km (500mi). The Space Shuttles rarely flew above 650km (405mi).

Dimensions
The X-37B measures just 8.8m (29ft) long with a 4.5m (14.7ft) wingspan. This makes it a quarter as long and a fifth as wide as the Space Shuttle.

Adrian Mann

5 Amazing facts

Dark matter

A giant galactic cluster 4.5 billion light years away showing gravitational lensing, which can be used to calculate how much dark matter it contains

© NASA

We can't see it

Dark matter doesn't emit or absorb any kind of electromagnetic radiation, so how do we detect its presence? Mostly, by the gravitational force it exerts on its surroundings, particularly gravitational lensing: here, light is bent around a distant object to such a degree that only a large amount of unseen mass - dark matter - can explain it.

There's much more dark matter than normal matter

Incredibly, all of the normal stuff we're able to observe amounts to less than five per cent of the universe, while dark matter accounts for a lot more - around 27 per cent. The rest is dark energy.

Einstein could have got it wrong

Dark matter might exist, or what we're observing could be very hard-to-detect objects like brown dwarfs or neutrino stars. Alternatively, it's possible the laws of gravity that have served us well so far are simply not up to the task of describing the larger scale of the universe effectively enough.

It was discovered in the Thirties

Not long after Hubble found that the universe was bigger than first thought, Fritz Zwicky observed that galaxies in the Coma cluster were moving so fast they should have flown apart. But they weren't: something massive and invisible - which he labelled dark matter - was holding them together.

No one knows what it is

We're able to define the nature of normal matter, but not dark matter. It's not made of protons or neutrons, it's not antimatter, or made of any other known particles. We know more about what dark matter is, in fact, by what we know it's not, which is why it's a contentious subject within the scientific community.

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The world's largest telescope

Astronomer Tyler Bourke, one of the scientists charged with bringing the Square Kilometre Array (SKA) to life, chats to **All About Space** about plans to explore the universe with the world's largest radio telescope

Interviewed by Gemma Lavender

INTERVIEWBIO

Tyler Bourke

A project scientist for the Square Kilometre Array, Tyler Bourke's scientific interests lie in the star formation of galaxies. He has worked as an astronomer at the Smithsonian Astrophysical Observatory and he has been associated with the Spitzer Space Telescope and the Chandra X-ray Observatory.

Radio astronomy is set to receive a huge boost in the next ten years with the creation of the Square Kilometre Array (SKA), a giant observatory built from two huge sets of radio dishes and antennas spread across two continents. The SKA, which will sport over 250 high and mid-frequency radio dishes in South Africa and an army of low-frequency antennas in Australia, will be the world's biggest telescope, observing the universe at radio wavelengths, searching for the pulses of spinning neutron stars and clouds of hydrogen gas. The aperture arrays of the SKA could produce so much data that it will need bandwidth the equivalent of that used by 100 times the world's current internet traffic. To handle all this information, its computers will need to be three times more powerful than the world's fastest current supercomputer.

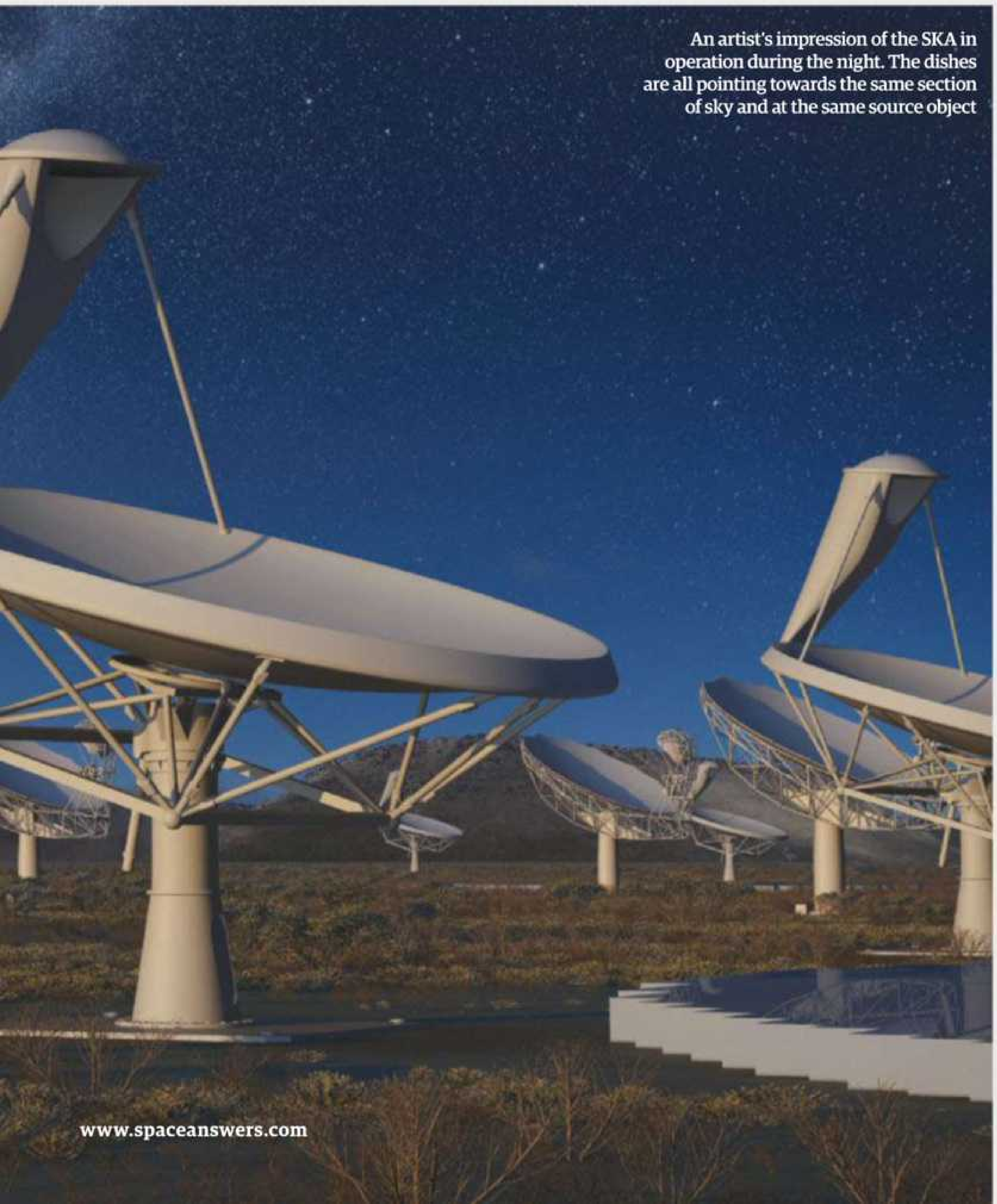
Could you tell us a bit about your role on the Square Kilometre Array (SKA)?

I'm one of the project scientists. I'm part of a science team of four people, which includes a director and three scientists. At this point, our role is to make sure that the telescope designs line up with the science that the astronomers plan to do with the SKA. These astronomers have a wish list and ideas of how to do it.

But there are also practicalities of what you can actually design and build for the money available - this means that some compromises need to be made as well as some technical assessments. It's important to try and make sure that when those assessments are done, the main science is not left until last and that it still drives the project. I guess we make the bridge between the outside astronomy community and the inside group of engineers and architects.

The SKA is currently in development. How's that going so far?

It's going very well, actually. Plans for the SKA have been on a very fast-paced timeline for the last two years and it's looking to proceed that way for the next two years. It is a very aggressive timeline. There has been a lot of talk about the SKA for a long time with a lot of the more grandiose ways of how the array should turn out, but not really any actions were taken. We've finally decided to put a plan into action to get it going very quickly. We're hitting all of the milestones, which is great but people are feeling the pressure and feeling the pinch. There have been a lot of people coming back with 'oh, we don't have enough information to do this and do that', but we're getting it done.



An artist's impression of the SKA in operation during the night. The dishes are all pointing towards the same section of sky and at the same source object

The SKA is being built in the southern hemisphere. Why is that?

Yes, there are two sites - there's one in South Africa and [one in] Australia. They are two of the quietest radio sites in the world. There is proof of this with there being a lot of data available from mapping missions in space and, of course, looking up from the ground. As you would expect, Europe is a hot spot for terrible radio interference, as is North America. Places where there aren't many people are great and South Africa and Australia fill that criteria. We also have the advantage of being close to first world countries with great infrastructure and supported governments. Those sites aren't too far away from major cities such as Cape Town. So all of those things help but it's all mainly driven by where you want to do the astronomy, which is the most important part.

What's so special about operating in radio wavebands?

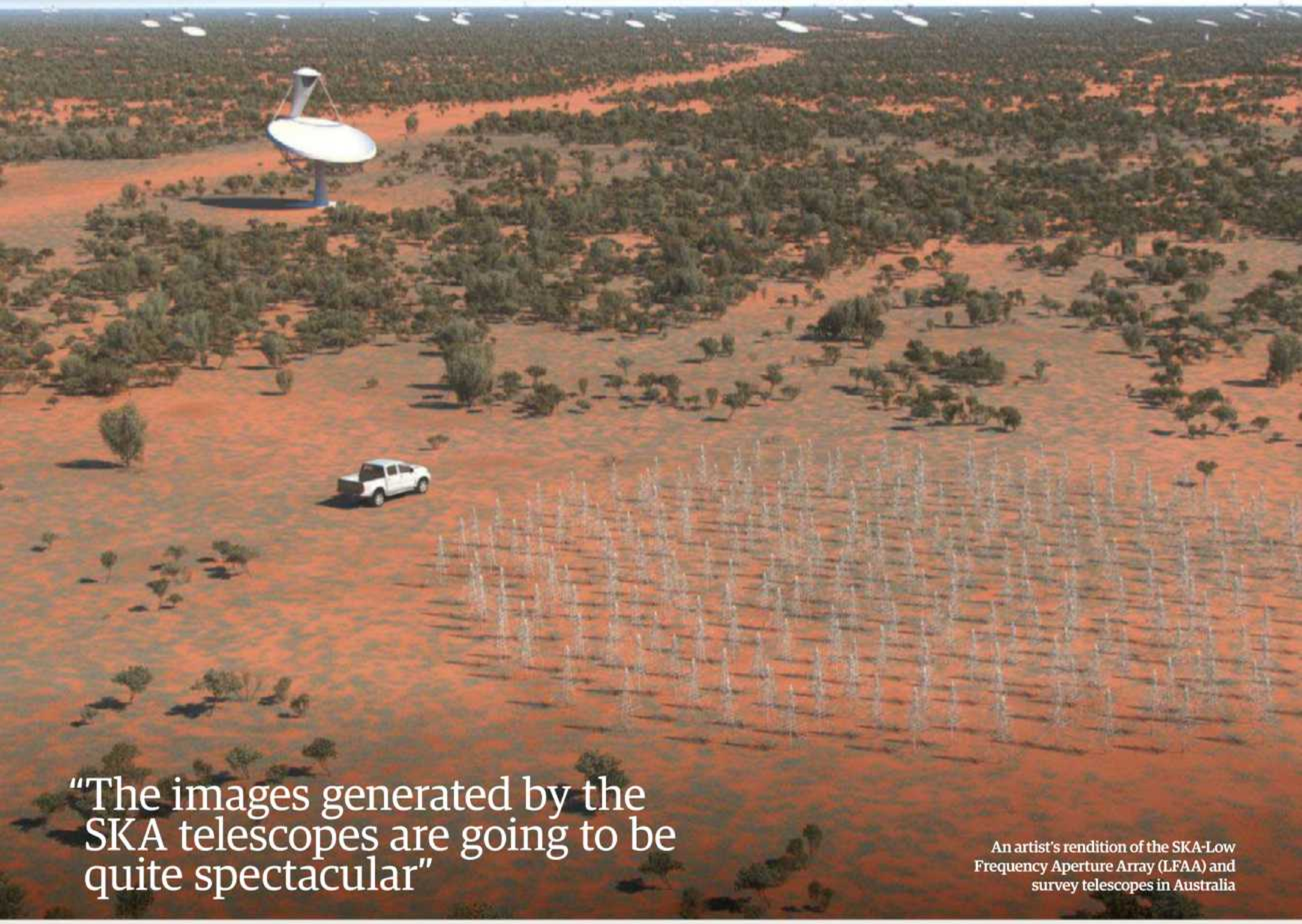
Well there's particular science that can only be done in radio wavelengths and you just need to look back at the last 30 or 40 years or so of astronomy - a lot of the big discoveries have been made at radio wavelengths. So particularly the pulsars, which were discovered in the UK, could not have been done in any other wavebands. I'd say that this is a very big example of needing to study the universe in radio wavebands. Things like looking at complex molecules, which are very interesting for people looking for life in the universe, is another example and one which is going very well in the radio wavelengths. And looking back in time is also very good in long radio wavelengths, since they can see through all of the obscuring matter in space in order to go way back to the beginning of the universe, which can be very hard to do at optical wavelengths and other wavelengths. It's the way that a lot of astronomy has been done.

The SKA is around 50 times more sensitive than any radio instrument ever built. How powerful and how large does the array have to be?

The largest current telescope is the Very Large Array in America and that has 27 dishes of 25 metres [82 feet]. So for the comparable telescope in South Africa, we will have over 250 dishes. That gives you two things - one is a much greater sensitivity, due to a large collecting area for you to not only be able to see the fainter things but for you to observe the sky much faster, and also a much larger area of the sky can be observed. So it's very good for looking at things that go off quickly, that flicker and are variable. You want to be able to be looking at as much of the sky as often as you can to pick things up. It also helps us to spread the antennas out quite a bit more, so our ability to resolve things is greatly increased. If you put those things together, it's very important.

How will the array work?

The resolving power of the telescope is strictly set by the largest separation between two antennas, or if it was a single telescope, the width of the telescope itself. So instead of having one big telescope, which is simply



"The images generated by the SKA telescopes are going to be quite spectacular"

An artist's rendition of the SKA-Low Frequency Aperture Array (LFAA) and survey telescopes in Australia

not possible - you can't build a single telescope that will match the size of the SKA, it wouldn't be able to support itself since it would be too expensive and it would just sag all over the place. We build a lot of small dishes and spread them out over a large area, so you don't quite have the aperture of a single telescope, but if you have a lot of them you get pretty close. The further apart they are, the better you can resolve something that is far away.

What will the images look like?

We colour the images by looking at different wavelengths. In radio it's not like optical light where there is natural colour associated with it. So [in radio] you can make pretty pictures and assign your own colour, but to do that you need observations at different frequencies or equivalent wavelengths - the telescopes of the SKA will do this. We're covering from the lowest frequencies of 50MHz and up to 15GHz, so that's a few orders of magnitude. You can make any images you want from that - they're going to be quite spectacular. And also, part of it is not imaging. Part of it is doing timing observations where you can't make images, you're just timing the blips from a pulsar. In that case you want to go back again over and over to observe the same object and time it over a long period to get exquisite solutions. Pulsars are great clocks, they are the best clocks in the universe, that's what we want to use them for.

Will the SKA work with other telescopes on the ground or in space?

There are two things there and one is to work with other radio telescopes. One thing we can do is link up the SKA telescopes in Australia and South Africa - not so much in real time but we'll take the data and there will be timing signals attached to all that data, and then you take them and combine them based on the time of the signals. At present in Australia there are other telescopes that can be connected to the Australian array. There are also plans to do this in Africa actually, there are many other countries in Africa that have these old tracking stations, these old dishes that would track satellites and take incoming signals and that are no longer in use, and they would have to refurbish a lot of those and connect them up to a big network, increasing the resolution very much.

The other way is to not just do the radio but to do other wavelengths at the same time, especially optical. There will be a telescope that is primarily being built by the US in Chile, the Large Synoptic Survey Telescope (LSST), which is planned to image the sky completely every three nights. That's something we can do as well, so astronomers will be very interested in that huge amount of data, they will be cross-referencing signals from both telescopes and that will be amazing.

Did you need to develop new technologies to build the SKA?

In the low-frequency range we're basically taking the first technologies used in radio astronomy, these very simple antennas. But now we can do things much smarter in software and the computing side of things, which allows you a lot more flexibility in using these simple antennas. For the other telescopes, we already understand what to do, it is the scale of the problem that is a deep factor for now: how do you handle the computing side of things? How do you handle the data rates? It is something that we haven't had to come across at this scale before. We're going to have to do a lot of things to address these questions and probably tap into areas of computing that are outside of astronomy and tap into some big cloud computing.

What do you hope to achieve with the SKA - will you be able to challenge Einstein?

Oh, Nobel Prizes! Seriously, there are some big questions that have been put forward to drive the telescope. One of them is in the area of Einstein's relativity and gravity in general. We know that Einstein's theories have held up over the last century extremely well and to exquisite detail - they are among the most tested theories out there. What we haven't been able to really do is test them in extremes of gravity, which are only found out in the cosmos. And we can do that with pulsars actually - they are the densest bodies we know of - so by looking at the pulsars and the timing of them we can really start to test Einstein's theory at the most extreme ends of the universe. Another thing we want to do is study when the first galaxies and the first stars formed, some billion years or a bit less after the Big Bang and that can only be done at radio wavelengths at which we study neutral hydrogen in the cosmos. Another thing we want to do is to use the hydrogen line to measure the distances to a billion galaxies right back to the start of the first stars and with those distances we can really test our cosmological models and see how our universe evolved. This is something that is very complementary to optical work but we can do so much better.

With its enormous aperture, will the SKA be able to make new discoveries?

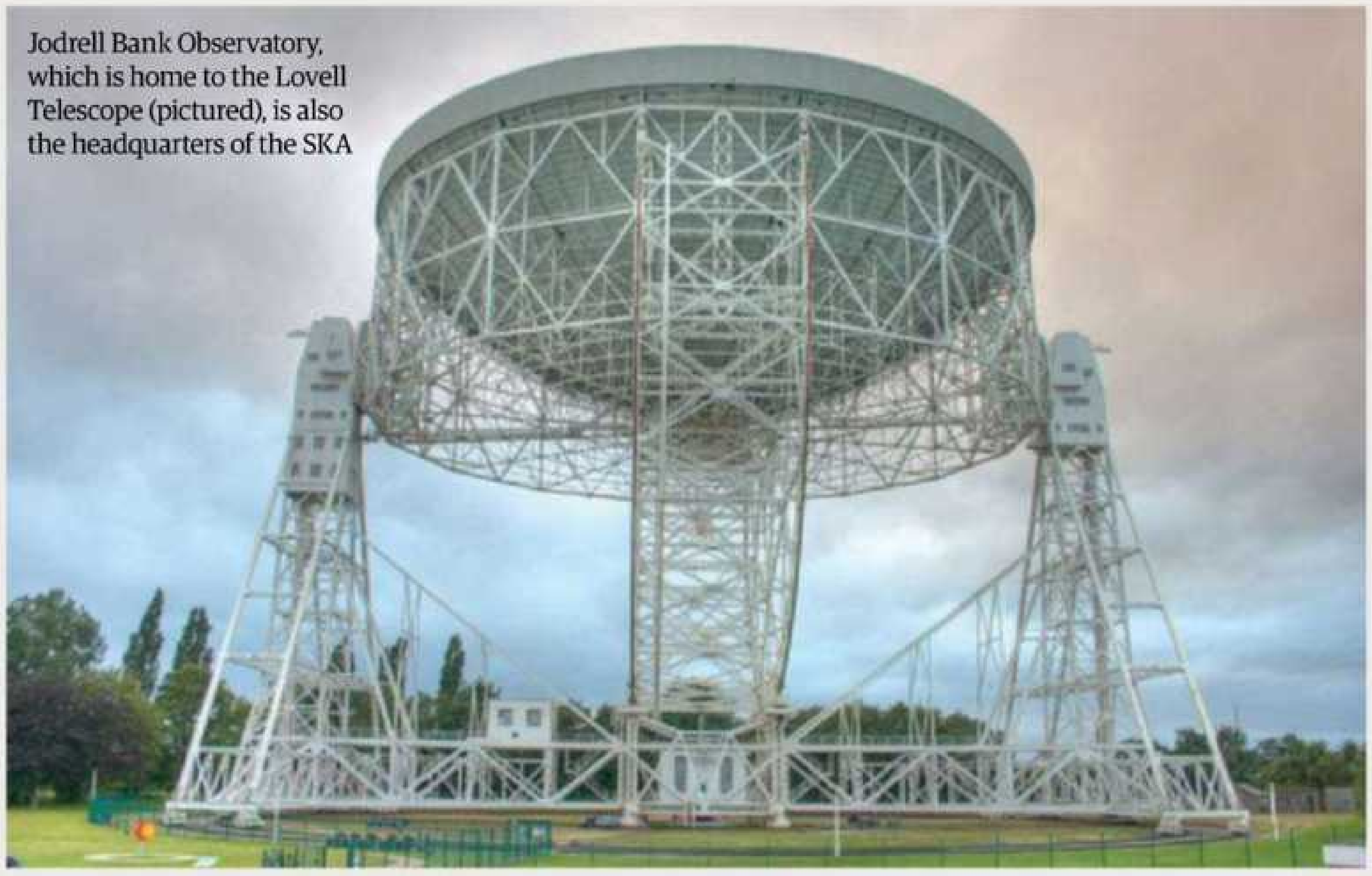
Yes, we have tried to design it to be flexible because much of the great work done by telescopes of the past, they weren't planned for that, especially in the radio field, so we need to make sure the telescope is flexible enough that there will be new discoveries. Many scientists are very interested in that possibility. They can say that we have the 'known unknowns', which are things that go off and are never seen again. You just need to be looking in the right spot at the right time, and a few of those have been found out there and they need a radio telescope like the SKA to find more and view the whole sky as often as it can at the sensitivity required. We know maybe what they are but the SKA will be able to see lots of these and will help decide what they are. Then, of course, there are the 'unknown unknowns' and you just have to be looking as much as you can all the time all over the sky and we're trying to design the telescope to be flexible to do that.

When will the SKA be operational?

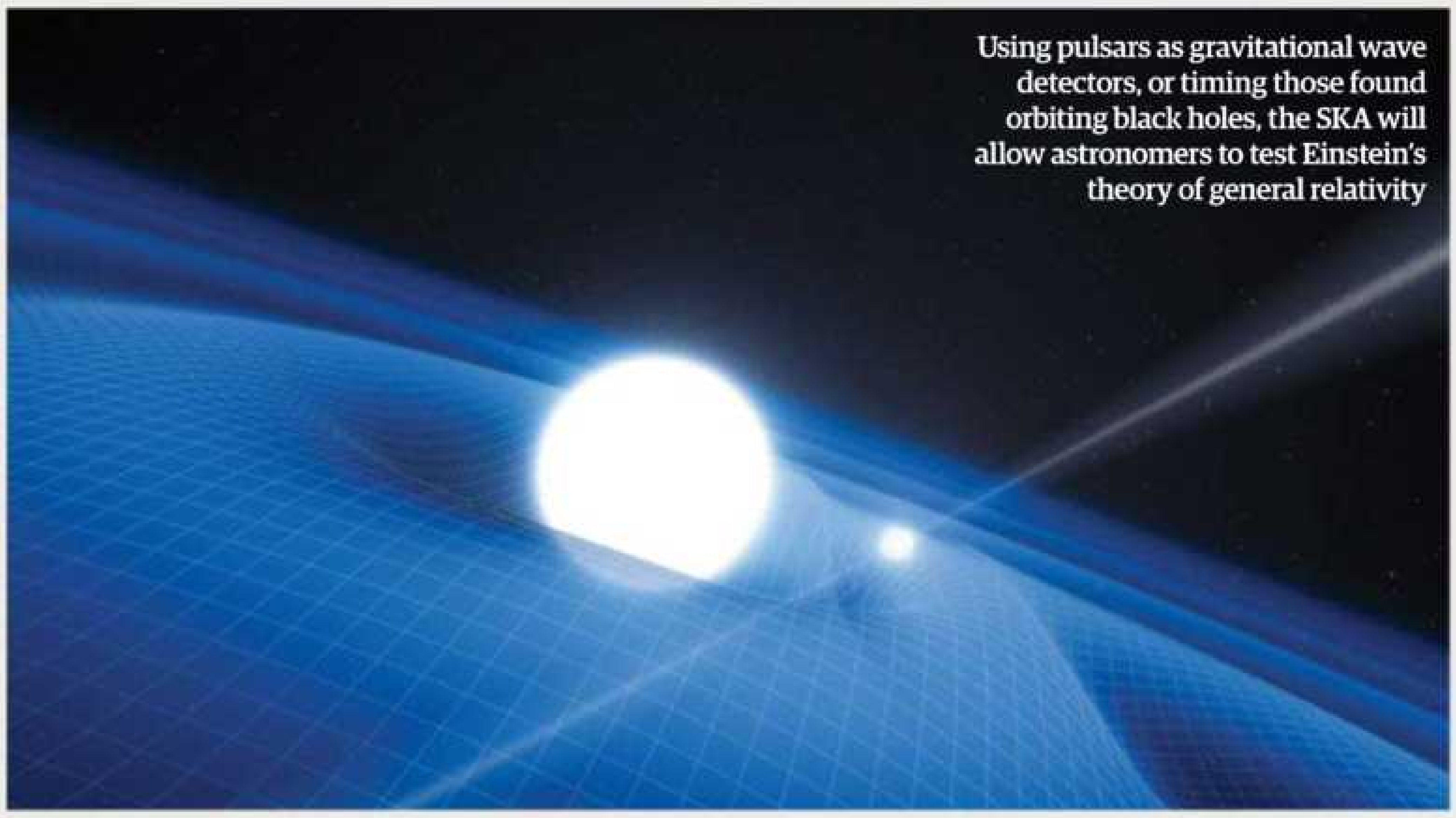
We are hoping to start construction towards the end of 2017, and we hope to have enough telescopes on the ground by the early 2020s to do some science. This is called Phase 1 at the moment, where we are trying to build something like ten per cent of the final product and this is to demonstrate to the governments putting their money into this that we can do what we say we're going to do, and that phase we hope will be done by 2023 or 2024. And from then, we will go into Phase 2 and hopefully build something a lot bigger.

So what will Phase 2 involve?

Phase 2 is supposed to be of the order of ten times bigger in many ways, and that will be a telescope that can last hopefully for 50 years. So that means we will have ten times more dishes in South Africa and in the low-frequency part of the telescope in Australia, I think it will expand by a factor of four or five times in actual numbers of antennas out in the field. This will be the equivalent of ten times in some ways but not in other ways. The cost won't be ten times more though, we'll be able to scale things up and understand how to do things better. ●



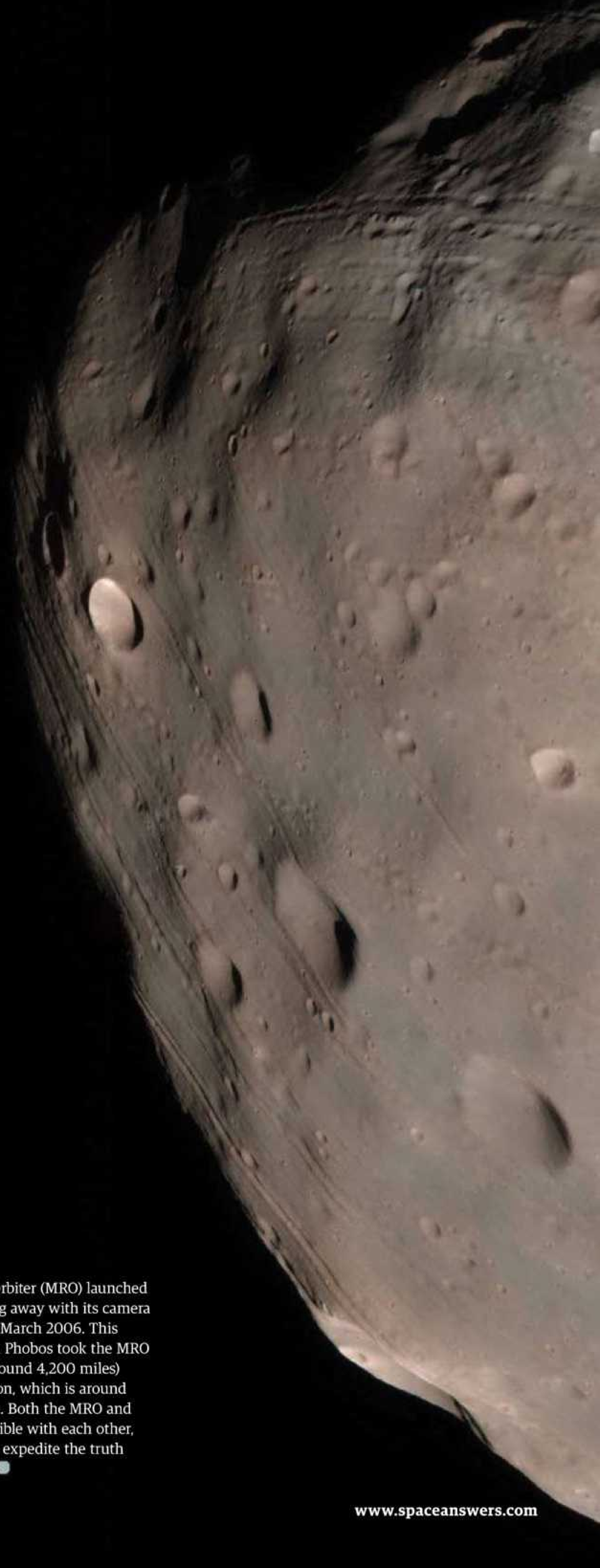
Jodrell Bank Observatory, which is home to the Lovell Telescope (pictured), is also the headquarters of the SKA



Using pulsars as gravitational wave detectors, or timing those found orbiting black holes, the SKA will allow astronomers to test Einstein's theory of general relativity

The SKA will be so sensitive that it will be able to map a billion galaxies out to the edge of the observable universe

© SKA; NASA; Mike Peel; Jodrell Bank Centre for Astrophysics, University of Manchester



The moon Phobos, shot in visible and near-infrared light by the Mars Reconnaissance Orbiter in 2008

Martian moon

Looming very close: the biggest of the Red Planet's two natural satellites is snapped by an orbiter

NASA's Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft entered into orbit around Mars last month and while it does have an ultraviolet imager, it has no camera. It doesn't need one for its mission, which is ultimately to determine what happened to the Red Planet's atmosphere. Fortunately, it's not alone out there around 225 million kilometres (140 million miles) away from Earth and in an orbit that takes it as close as 150 kilometres (93 miles) above Mars.

The Mars Reconnaissance Orbiter (MRO) launched in 2005 and has been snapping away with its camera in multiple wavelengths since March 2006. This stunning close encounter with Phobos took the MRO to within 6,800 kilometres (around 4,200 miles) of this face of the Martian moon, which is around 22 kilometres (13.7 miles) wide. Both the MRO and MAVEN's missions are compatible with each other, and together should hopefully expedite the truth about Mars's mysterious past. ●

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Sophie Allan

National Space Academy Education Officer

- Sophie studied Astrophysics at university. She has a special interest in astrobiology and planetary science.

Zoe Baily

National Space Centre

- Zoe holds a Master's degree in Interdisciplinary Science and loves the topic of space as it unites different disciplines.

Josh Barker

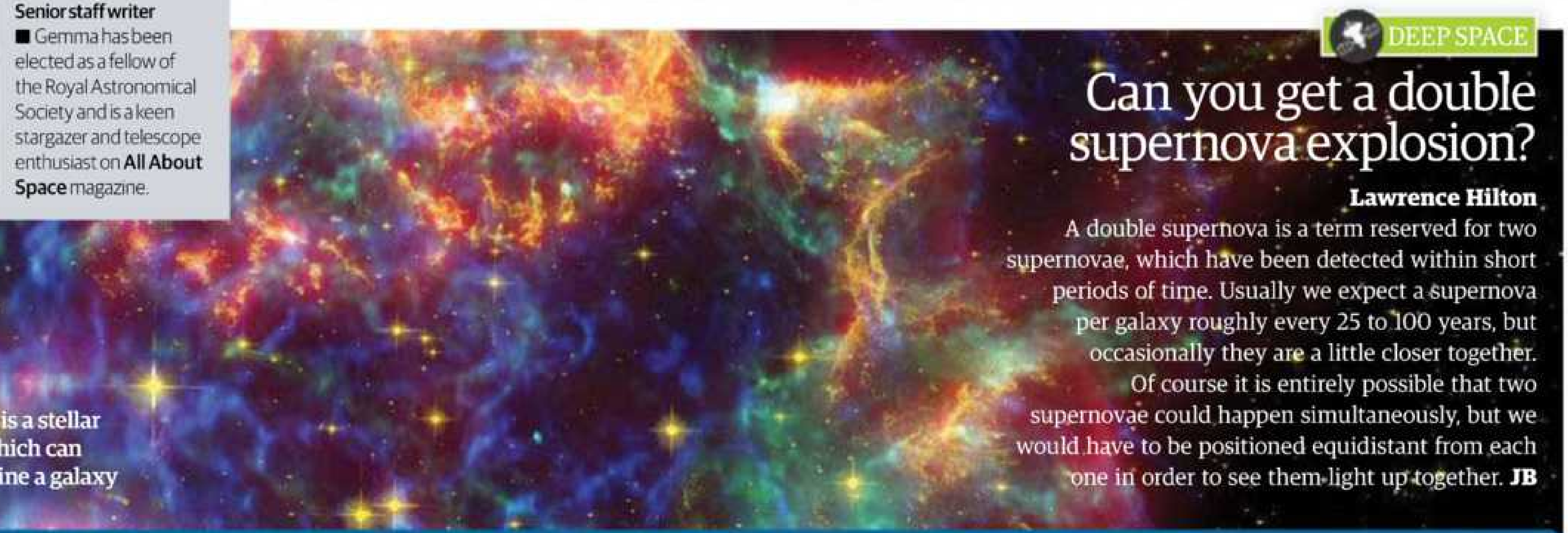
Education Team Presenter

- Having earned a Master's in Physics and Astrophysics, Josh continues to pursue his interest in space at the National Space Centre.

Gemma Lavender

Senior staff writer

- Gemma has been elected as a fellow of the Royal Astronomical Society and is a keen stargazer and telescope enthusiast on **All About Space** magazine.



A supernova is a stellar explosion, which can briefly outshine a galaxy

DEEP SPACE

Can you get a double supernova explosion?

Lawrence Hilton

A double supernova is a term reserved for two supernovae, which have been detected within short periods of time. Usually we expect a supernova per galaxy roughly every 25 to 100 years, but occasionally they are a little closer together. Of course it is entirely possible that two supernovae could happen simultaneously, but we would have to be positioned equidistant from each one in order to see them light up together. **JB**

Make contact: @spaceanswers /AllAboutSpaceMagazine questions@spaceanswers.com

NASA's Space Shuttle is unlikely to come out of retirement

SPACE EXPLORATION

Will the Space Shuttle programme ever make a comeback?

Denise Hadlow

The symbol of American spaceflight for 30 years, NASA's Space Shuttle programme (or Space Transportation System (STS) as it was officially known) retired permanently in July 2011. Even though NASA does not have a replacement spacecraft, the Space Shuttle will not be coming out of retirement.

Through a combination of physical age and the quality of the Shuttles themselves, as well as the cost of running the programme, it is just not feasible to bring them back. Following the Columbia Shuttle accident in 2003, it was decided that the programme had to be brought to an end.

Instead, NASA is currently focusing its resources on developing spacecraft capable of exploring beyond low Earth orbit – to asteroids and potentially even Mars. As such, private companies such as SpaceX are receiving funding to work on potential replacements for orbital missions. **SA**

Keeping a record of your observations provides a book of stargazing memories

ASTRONOMY

What's the best way to keep a journal of my stargazing sessions?

Keith Highland

The best way of keeping a journal of your sessions is simply using a small notepad and pencil! You can note down any important information about your observations and make sketches of anything interesting you see without ruining your night vision like you would if you used an electronic device. Note down as much information as you can, such as time, location, date and weather as well as what you managed to spot.

After a session some astronomers enjoy sharing their experiences by posting up notes into a blog, online forum or other sharing methods. In the end, it is all just a matter of finding out what is best for you. **ZB**

SOLAR SYSTEM

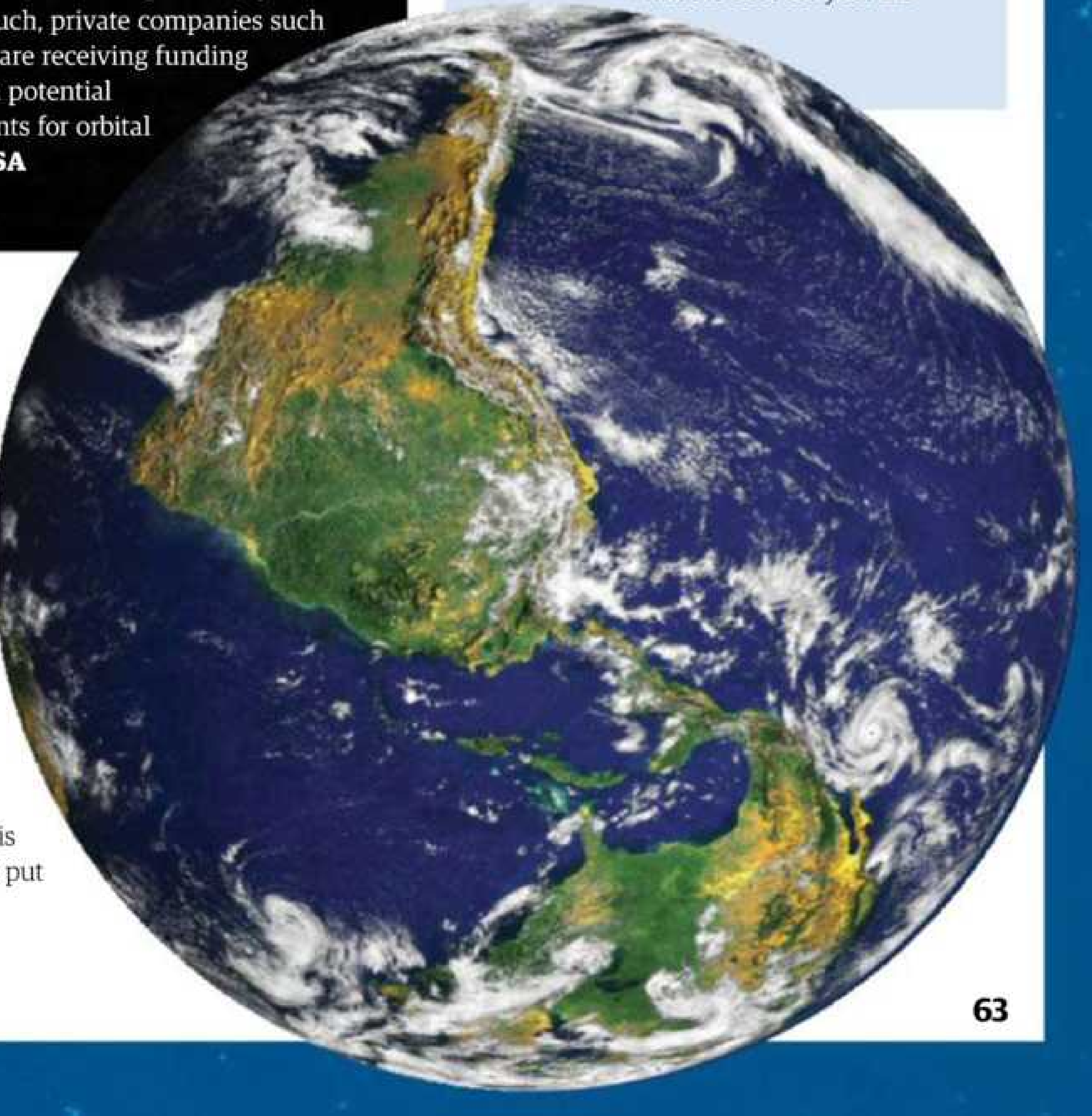
What would happen if we turned Earth upside down?

Darren Hunter

If you put all of the physical impossibilities of actually turning the Earth upside down aside, a flipped Earth would not only have its southern hemisphere at the top but the direction of our planet's rotation – as seen if you were able to get a bird's-eye view of Earth from above – would be reversed from counterclockwise to clockwise.

This would cause the Moon and stars to move in the opposite direction to what we're used to with lunar and solar eclipses being observable from an opposite hemisphere. Additionally, the seasons would be reversed with animals (as well as us!) getting quite confused by the change – we would suffer from a bit of jet lag, for example.

With no known forces actually capable of flipping the Earth upside down, though, this is something which could never be put into practice. **GL**



The Apollo 12 crew destroyed a camera after accidentally pointing it towards the Sun

ASTRONOMY

Should I use a CMOS or CCD imager for astrophotography?

Mark Foster

CMOS (Complementary Metal-Oxide-Semiconductor) and CCD (Charge Coupled Device) are both types of sensors used in digital imaging. Both use slightly different methods of operation and setup, therefore have pros and cons for certain uses.

In general there is a small bias towards CCD in astrophotography. This is due to the signal-to-noise performance of the sensor. This allows them to be more accurate over long-exposure shots. This is also aided by a more uniform readout across the entire sensor, something that some CMOS chips struggle with. It isn't all bad news for CMOS devices though as they in general have much faster readout times and it's a much younger technology than CCD so improvements are being made much quicker. **JB**

CCD sensors tend to be more accurate over long-exposure shots

SPACE EXPLORATION

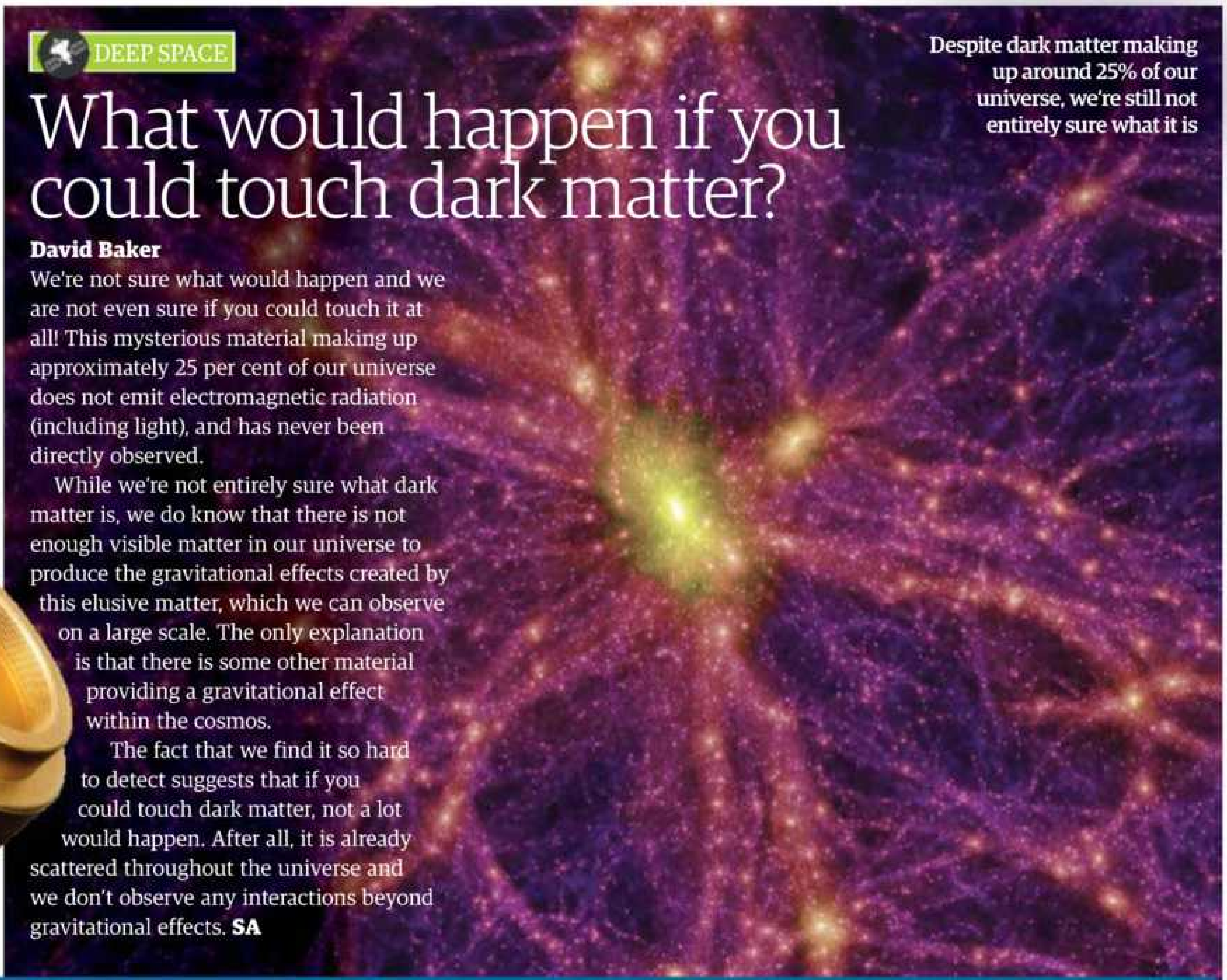
Did the Apollo astronauts take any photos of the Sun from the Moon?

Daniel Heinzmann

While the Apollo astronauts took many photos of the Earth and lunar surface, they took no images of the Sun. Without the Earth's atmosphere protecting their cameras from harmful solar radiation, our star is able to destroy any imaging equipment.

This is very much what happened to Lunar Module pilot Alan Bean of Apollo 12. Bean and mission commander Charles Conrad carried the first colour television camera to the lunar surface but within minutes the transmission was lost after Bean accidently pointed the camera at the Sun. The camera had been completely destroyed due to the intense brightness and radiation thrown onto the Moon's surface.

After leaving lunar orbit though, the crew of Apollo 12 did manage to catch a solar eclipse when the Earth passed in front of the Sun. **GL**



DEEP SPACE

What would happen if you could touch dark matter?

Despite dark matter making up around 25% of our universe, we're still not entirely sure what it is

David Baker

We're not sure what would happen and we are not even sure if you could touch it at all! This mysterious material making up approximately 25 per cent of our universe does not emit electromagnetic radiation (including light), and has never been directly observed.

While we're not entirely sure what dark matter is, we do know that there is not enough visible matter in our universe to produce the gravitational effects created by this elusive matter, which we can observe on a large scale. The only explanation is that there is some other material providing a gravitational effect within the cosmos.

The fact that we find it so hard to detect suggests that if you could touch dark matter, not a lot would happen. After all, it is already scattered throughout the universe and we don't observe any interactions beyond gravitational effects. **SA**

Questions to... @spaceanswers /AllAboutSpaceMagazine questions@spaceanswers.com

SPACE EXPLORATION

What does NASA's Deep Space Network do?

Abbie Hannah

The Deep Space Network is NASA's international array of giant radio antennas, which is capable of supporting spacecraft on interplanetary missions as well as those that are put in orbit around Earth. The array is also able to make astronomical observations of our Solar System and the larger universe using radar and radio wavelengths. It's the largest and most sensitive scientific telecommunications system in the world.

Currently, the network consists of communication complexes about 120 degrees apart and based in California, Spain and Australia, with each facility situated in partially mountainous, bowl-shaped terrain to assist with shielding against interference from other radio sources. In a clever twist, the 120-degree placement means that spacecraft can continually be observed as the Earth spins on its axis. **GL**

The Canberra Deep Space Communication Complex in Australia

SPACE EXPLORATION

Are there any animals in space at the moment?

Harry Isaacs

Earlier this year, five geckos - small lizards famous for their ability to walk up walls - were sent up to space in a Foton-M4 satellite by Russia. The reptiles were part of an experiment to study the effects of microgravity on their behaviour. The Russians lost control of the satellite for a few days but restored contact again before the geckos' food supply ran out. Sadly, not long after that and on 1 September, Russia confirmed the death of all five geckos and stated that it's likely that the reptiles struggled in the low temperatures of space. Most recently, a SpaceX resupply mission delivered 20 mice to the ISS. Scientists will observe them to study the effects of microgravity on rodents. **GL**

Quick-fire questions

@spaceanswers

Can the Milky Way really cast a shadow?

When there is no Moon and the sky is pitch black, the Milky Way can be seen to cast a shadow on the ground. You would need ideal conditions to see it though.

How fast are Neptune's winds?

The fastest recorded wind speeds on Neptune can get as high as 2,400 kilometres (1,500 miles) per hour, making this planet the world with the strongest winds in the Solar System.

How big is the Chicxulub crater in Mexico?

The crater made by the asteroid that is said to have helped wipe out the dinosaurs is around 180 kilometres (1112 miles) in diameter and 20 kilometres (12 miles) in depth.

How did dwarf planet Haumea become ellipsoidal in shape?

This dwarf planet is thought to be rotating so rapidly that it has been distorted into an elliptical shape.

Can moons have rings?

It is possible for a moon to have rings - for example, Saturnian moon Rhea is thought to have a tenuous three-ring system.

Do reflector telescopes use lenses?

Unlike the refractor telescope, which must use lenses to bend light, a reflector telescope needs to use mirrors to reflect light to form an image of the object that's being observed.

How do black holes grow?

Black holes get bigger and grow in mass by capturing the material nearby using their very strong gravitational pull. Anything that enters a black hole's event horizon can no longer escape, therefore becoming swallowed and increasing the black hole's size.

Quick-fire questions

@spaceanswers

Can planets form in binary star systems?
Yes, they can - even in triple star systems! Among the many planets discovered, several have been found in these systems - examples are the systems 16 Cygni and 55 Cancri A.

What is an accretion disc?
This is a disc of material - usually gas and dust - often found around massive objects such as stars or black holes.

Are there any planets like our own?
Given the size of the universe, it is possible. However, while we have found rocky worlds of similar size to the Earth we haven't confirmed any worlds just like our own yet.

Is there gravity in deep space?
Gravity is what keeps galaxies together and alien planets around their stars - so there is definitely gravity in deep space.

What is a 'Goldilocks zone'?
This is the distance from the Sun or a star that has planets, where it's not too hot or too cold and where liquid water can exist.

What would plants look like on an Earth with two suns?
According to research, experts think that it's likely that plants on a planet orbiting two suns will be black or grey rather than the green we're used to on Earth.

Does Venus cool down?
Venus doesn't have seasons like Earth. With its small axial tilt of just 2.7 degrees, the planet experiences no temperature variations at all.

Sunset on Mars taken by the Curiosity rover

ASTRONOMY

What would astronomy be like on Mars?

Tim Bennett

It wouldn't be too dissimilar from astronomy on Earth. Without an ozone layer though, you would have the added advantage of being able to make ultraviolet observations of the Sun from the surface of Mars.

As seen from the Red Planet, Earth and our Moon appear star-like to the naked eye. With the use of a telescope, you would be able to see them as crescents along with some detail on both surfaces of these worlds. Mars's moons - Phobos and Deimos - would also be seen in the Martian night sky. Phobos would appear about a third the size of our Moon while Deimos would be a star-like point. Other phenomena such as comets and meteors can also be seen from the Red Planet as proven by the rovers on its surface. **JB**

The Solar System's planets would cool if a Dyson sphere surrounded the Sun

SOLAR SYSTEM

Would a Dyson sphere around our Sun affect the planets in our Solar System?

Fariah Amin

If we were able to construct the theoretical Dyson sphere around our Sun our planets would no longer receive as much energy. This would cause the planets to cool and create a knock-on effect on their environments.

A Dyson sphere is a theoretical shell (first suggested as a thought experiment by Freeman Dyson) that could be constructed around a star and would be capable of collecting most, if not all, of a star's energy. As a planet only receives a tiny proportion of the energy radiated out from its star, Freeman suggested that an advanced civilisation with high energy requirements would be able make the most of their star by constructing and using a Dyson sphere. **ZB**

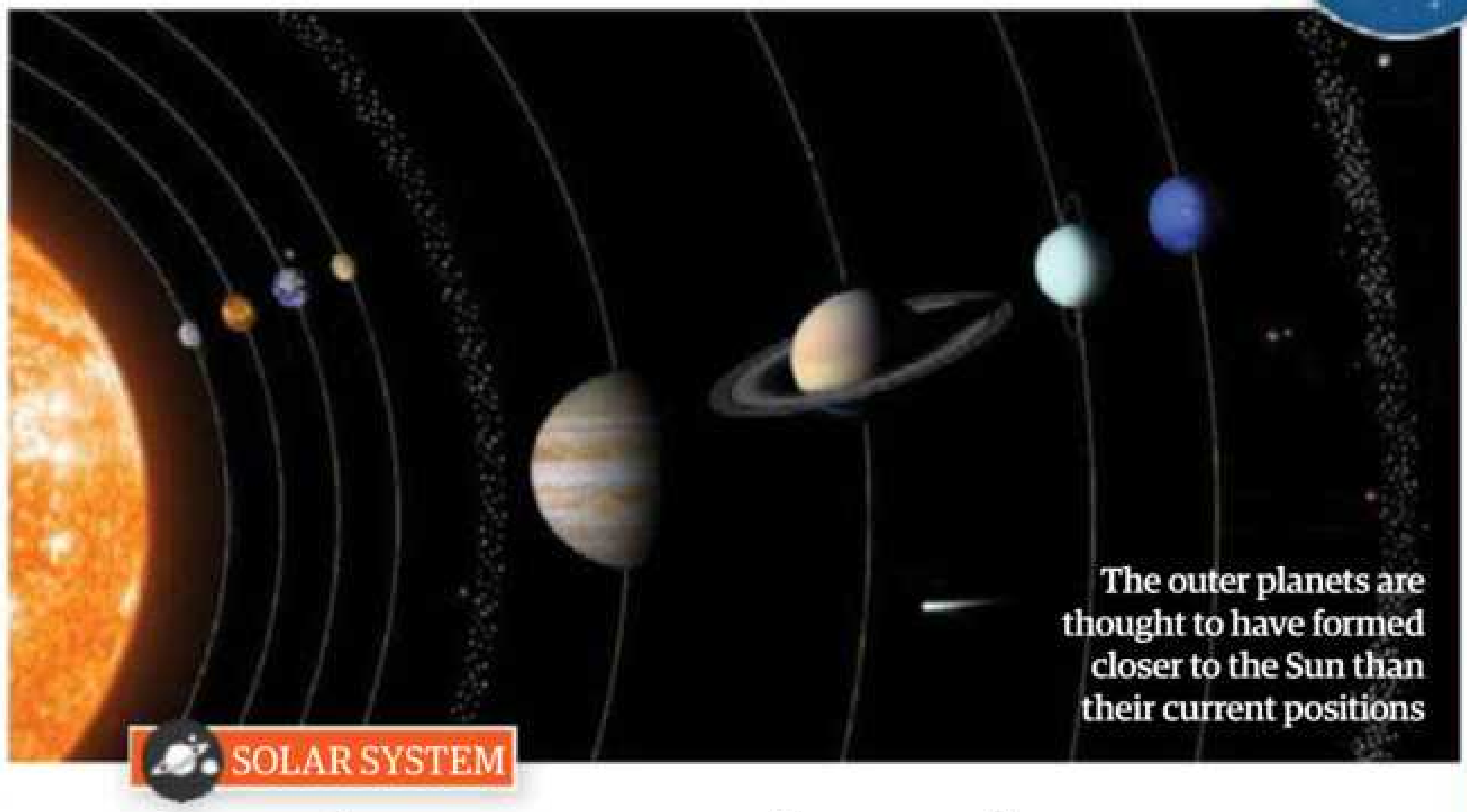
Currently, the 'Swarmies' patrol the surroundings of the NASA space centre in Florida

SPACE EXPLORATION

What will NASA's new 'Swarmies' robots help us to achieve?

Vernon King

NASA's 'Swarmies' may help us to explore and gather resources on the Moon, planets and asteroids. Groups of these small-wheeled robots could be sent to an alien landscape and given a target mineral or resource to find. Once set free, the 'Swarmies' would work in a similar fashion to an ant colony. Each would head off separately in search of their objective, covering plenty of ground. Once a robot successfully spots its target it's able to call its fellow 'Swarmies' to come and help mine. As well as out in space, these robots may also help out here on Earth, by assisting with search and rescue missions. **ZB**



The outer planets are thought to have formed closer to the Sun than their current positions

SOLAR SYSTEM

Are inner rocky planets able to form in the outer planet's positions?

Jack Simms

No, it's not possible, although it is believed that the outer planets could not form in their current locations either - this statement obviously fundamentally rocks our understanding of the Solar System.

Current research shows that the rocky planets probably formed in their current locations but the outer planets must have been much closer than they are today. This is due to how we think the material must have initially been distributed. To produce the arrangement we see now, the planets are thought to have undergone some migration. This unstable period, around 700 million years after the Solar System formed, saw the outer planets drift outward. We call this the Nice model and it's our best guess at how the Solar System formed. **JB**

NGC 7742 is a classic example of a type II Seyfert galaxy with its bright core and tightly wound spiral arms

DEEP SPACE

What is a Seyfert galaxy?

John Cope

Powered by a black hole munching on material at the centre of their galactic structure, Seyfert galaxies are highly energetic and have bright compact cores, which spit out lots of strong infrared emission. They come in two types - type I and type II, with the former possessing faster-moving hot gas than the latter.

Seyfert galaxies are intensely studied since they are thought to be powered in the same way as the more luminous and faraway quasars - being much closer means that we can try to get a better understanding of both quasars and Seyferts at the same time. Seen in visible light, both Seyfert galaxies look very much like normal spiral galaxies. While under other wavelengths, their core luminosity is of comparable light intensity to the whole Milky Way! **ZB**

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Next Issue

INTERSTELLAR SPACE TRAVEL

Is warp speed to another star system really possible?

VENUS: EARTH'S EVIL TWIN

Explore one of the most inhospitable worlds in the Solar System

BLACK HOLES: 50 AMAZING FACTS

All you need to know about the most powerful force in space

PICK THE RIGHT TELESCOPE

A complete guide to choosing and using your perfect telescope, whatever your experience

+

3D GALAXY MAPPER
STARDUST MISSION
X-RAY SPACE TELESCOPE
I DISCOVERED AN EXOPLANET
RICHARD DAWKINS INTERVIEW
OBSERVER'S GUIDE TO NEPTUNE

In orbit
13 Nov 2014

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The latest essential astronomy gear and telescopes reviewed

GET STARTED IN ASTRONOMY

Confused about which telescope to buy? Don't know your way around the night sky? Then you've come to the right place!

Learn how to...

...follow the night sky

The first thing every budding astronomer needs is an understanding of the ebb and flow of the stars, planets and constellations. It's not much good being a telescope whizz if you don't know what you can see in your area and when.

...star hop and use charts

It's best you get a bit of practice navigating the sky manually before you commit to buying a telescope. We'll show you how to use some of the most useful tools in an astronomer's inventory - including your own eyes!

...buy your perfect telescope

Once you've got the gist of finding your way around the cosmos, it's time to pick up a telescope and learn how to use it. But which one? We've advice on buying the right telescope for you, with tips on avoiding the pitfalls of being a first-time buyer.

...find stunning cosmic sights

Finally: this is what it's all been leading to. You now know how to find the stars, planets and nebulae, and you have the equipment, too. We'll show you what we think are the top targets for beginners and how you can best observe them.

Understanding the night sky

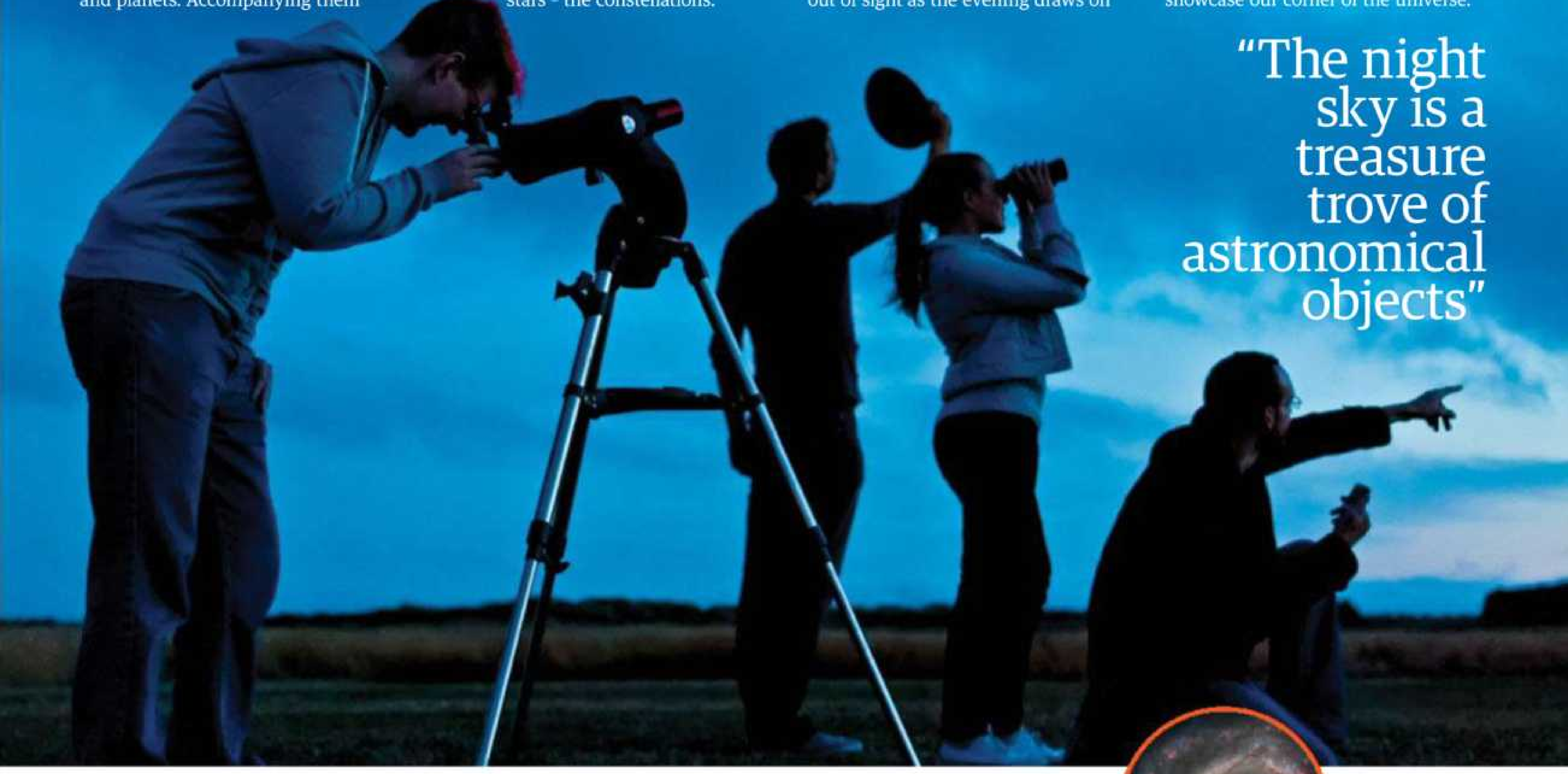
Discover the celestial sphere above you and how it moves with the seasons

The night sky is a treasure trove of astronomical objects that seem to be packed into every degree above our heads at any one time. When we set foot outside, it's like standing under a dome of blackness, pitted with the twinkling of countless stars, galaxies and planets. Accompanying them is the occasional appearance of the Moon and movement of satellites that make their way on their orbits around our planet.

From this dome-shaped window that looks out into space, we can recognise familiar patterns of stars - the constellations. These seem to wheel from east to west (or the opposite direction if you're in the southern hemisphere) with every pirouette our Earth makes on its axis and path around the Sun. With every turn, our planet slowly takes these stellar patterns out of sight as the evening draws on before bringing them into view the following evening. This star-studded bubble extends from north to south, enveloping the planet in an imaginary ball that changes either side of the equator. With this visualisation, you can see why astronomers call it the celestial sphere.

It's easy to think that the night sky is fixed throughout the year, but this isn't the case. The more familiar you become with the heavens, the more you'll notice that it changes with the seasons. And, as winter moves from spring through to summer, autumn and back round to winter again, different constellations as well as other night sky wonders, like the planets, galaxies and nebulae, make their way into our line of sight to showcase our corner of the universe.

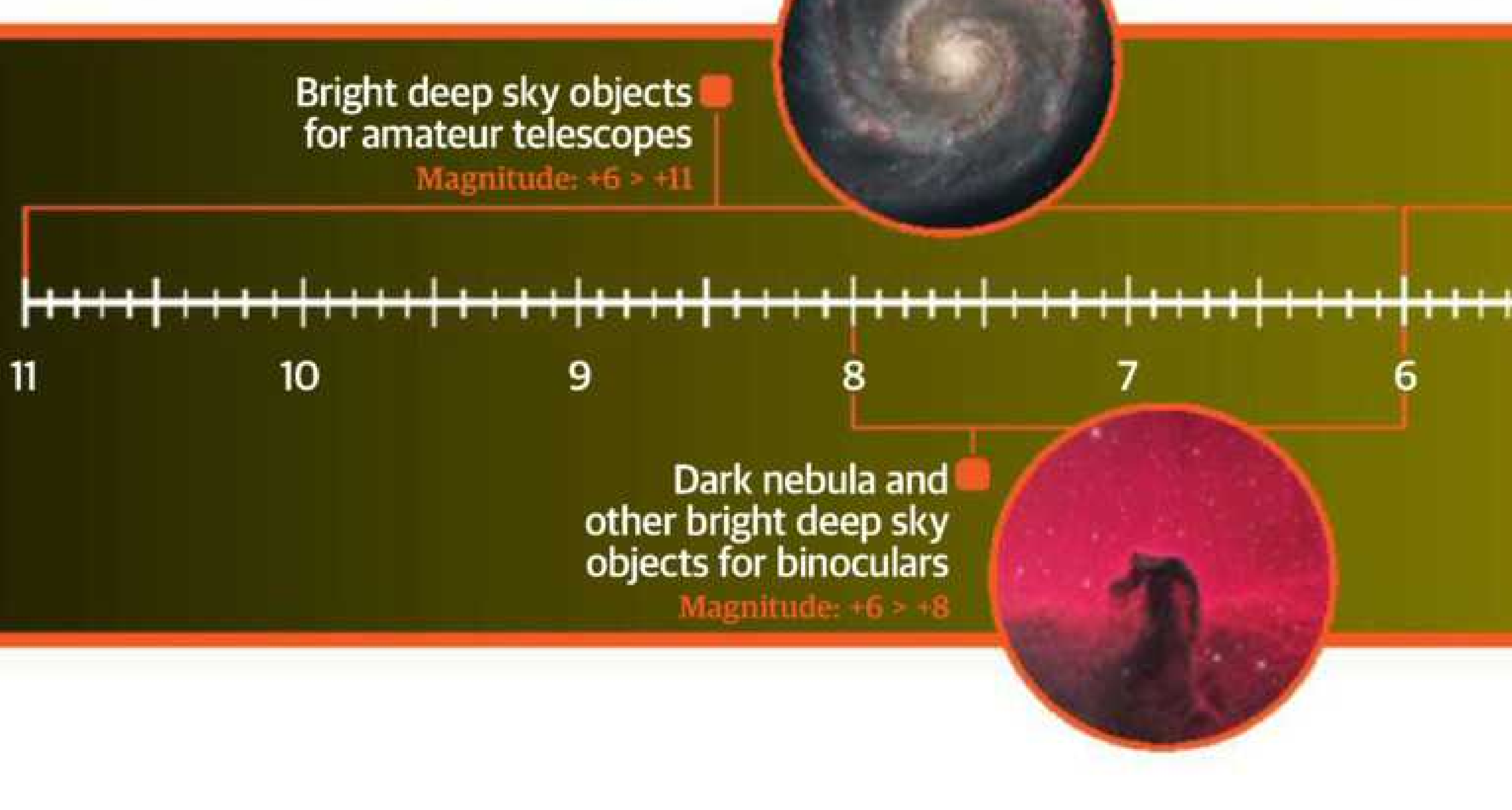
> "The night sky is a treasure trove of astronomical objects"



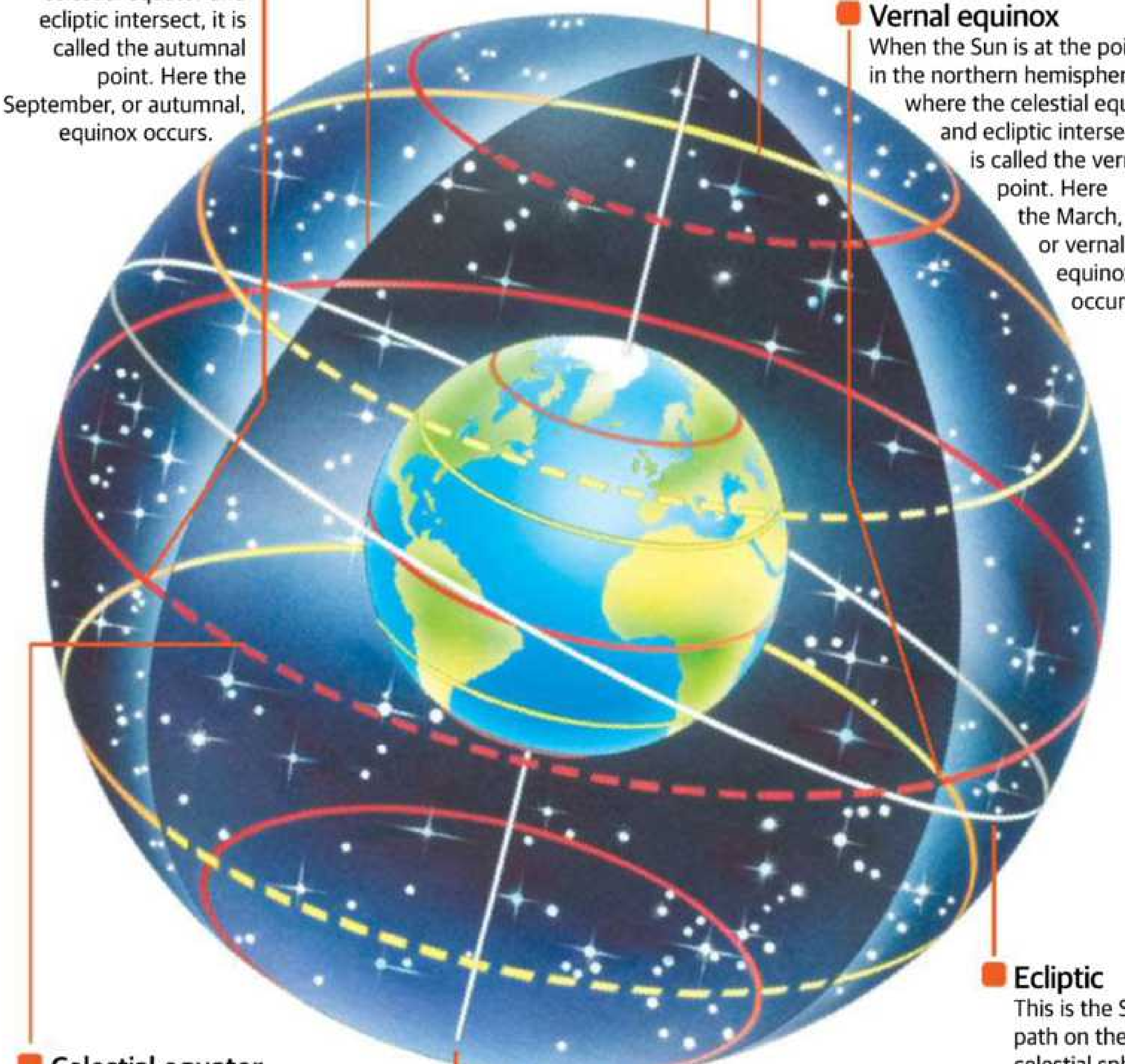
How to measure star brightness

The night sky is pocked with thousands of stars of varying brightness. When it comes to stepping outside for the first time, you'll likely find that your eyes are immediately drawn to the most luminous stars in the night sky.

The varying brightness of stars as well as other objects are measured using what astronomers call a magnitude system. The brighter the object, the lower the magnitude number. It scales exponentially, so a difference of five magnitudes means a difference of 100 times the brightness.


Bright deep sky objects for amateur telescopes
Magnitude: +6 > +11
11
10
9
8
7
6
Dark nebula and other bright deep sky objects for binoculars
Magnitude: +6 > +8

Exploring the celestial sphere



Autumnal equinox
When the Sun is at the point in the southern hemisphere where the celestial equator and ecliptic intersect, it is called the autumnal point. Here the September, or autumnal, equinox occurs.

Declination (Dec)
Imagine this as the latitude of the Earth, projected on to the celestial sphere. Declination is measured in degrees (°), minutes (') and seconds (").

North celestial pole
The northern point in the sky, around which all of the stars seem to rotate. Directly above the pole lies the North Star, also called Polaris.

Right ascension (RA)
The celestial equivalent of terrestrial longitude, projected on to the celestial sphere. Right ascension is measured in hours (h), minutes (m) and seconds (s).

Vernal equinox
When the Sun is at the point in the northern hemisphere where the celestial equator and ecliptic intersect, it is called the vernal point. Here the March, or vernal, equinox occurs.

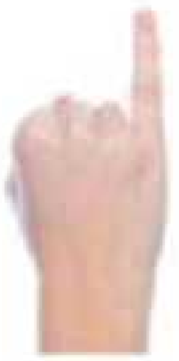
Ecliptic
This is the Sun's path on the celestial sphere, as seen if you were on the equator at the Earth's surface.

Celestial equator
A great circle on the celestial sphere, which lies in the same plane as the Earth's terrestrial equator and is tilted at roughly 23 degrees to the ecliptic.

South celestial pole
Only visible from the southern hemisphere, stars rotate around the South Pole. The closest star to the South Pole is the dim Sigma Octantis.

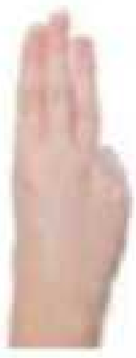
Measuring distances

"The Moon is about half a degree in diameter," an astronomer might have told you. We know it to be larger than the dwarf planet Pluto, so what does this mean? From Earth, our Moon is quite a small disc in the sky. In fact, you could probably cover it with your thumb. And that's where your hands come in - they are an excellent tool to roughly measure the size of night sky objects from your location on our planet. What's more, they can also be useful in measuring the distance from one celestial target to another.



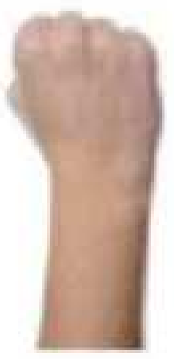
One degree

Fully extend your arm and hold out your little finger. This digit roughly equates to one degree on the sky. Remember, the full moon is about half a degree in diameter.



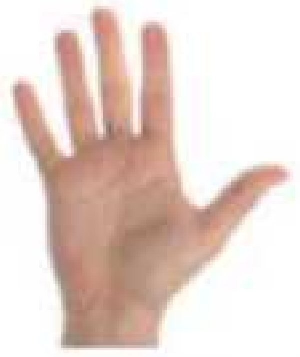
Five degrees

Ensure your arm is stretched out, hold out three fingers to measure a distance of five degrees between two objects - around six times the width of the full Moon.



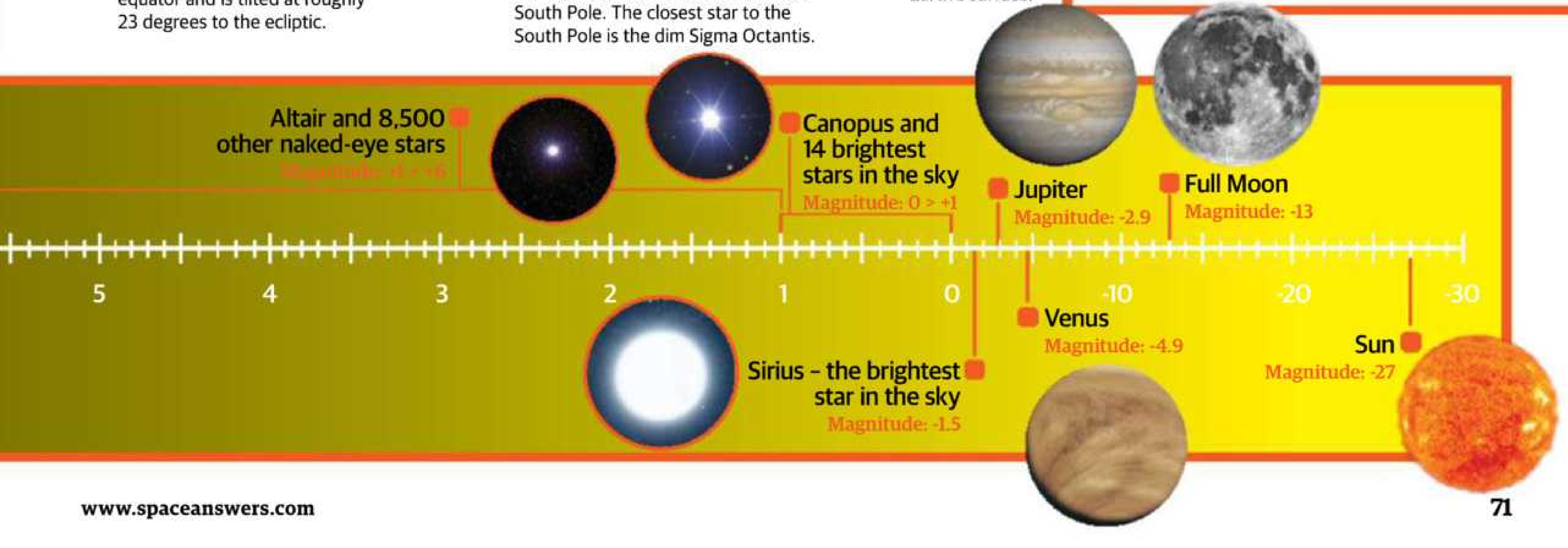
Ten degrees

Your fist measures about ten degrees apart. In other words, if you could fit your fist snugly between two objects in the sky, then they would be ten degrees apart.



20 degrees

Holding out your arm in front of you and spreading out your fingers will give you an approximate measurement of around 20 degrees.



Navigating the cosmos

Learn to find your way around the stars with just a few basic tools

If you thought that you needed a telescope or a pair of binoculars to take part in astronomy, then you would be mistaken. The beauty of observing the night sky is that anyone can get involved whether you have optical aids or not. All you really need are dark, clear skies - preferably without the Moon. The darker and the clearer they are, the better. What you might not be aware of is that there's still plenty in the night sky to be observed with your eyes alone - and not just the stars that comprise the dusty trail of the Milky Way, or the cratered lunar surface. Some of the planets and comets as well as galaxies are all visible to an observer without any fancy equipment. Simply identifying an object even without observing it in detail through a pair of binoculars or telescope, really is a rewarding experience in itself and a wonderful concept to behold.

Now that you've been acquainted with the celestial sphere, you are ready to venture outside. Looking out into space, you'll be able to see the brightest stars and you might be able to name some of them from guides you've read. Don't worry if not - there's plenty of time to familiarise yourself with what the skies have to offer. You might find it useful to purchase a planisphere or star map to help you to learn some of the objects that you'll eventually encounter - and most importantly, the constellations. Remember, if you're using a star map, then you will also need a red light torch to be able to see it. Unlike white light, red light won't ruin your dark-adapted vision, which you'll need if you want to be able to see dimmer stars of magnitude 5 or less.

Ensuring that you're wrapped up against the elements and have a hot drink to hand, you can now start by doing a spot of naked-eye astronomy. Your best bet is to head outside when it's clear and from a site as free of light pollution as possible. A cloudy sky as well as pesky glare from a nearby street light will only hinder your session, so it's often best - and less frustrating - to get to the darkest site you can and check the weather forecast before setting out.

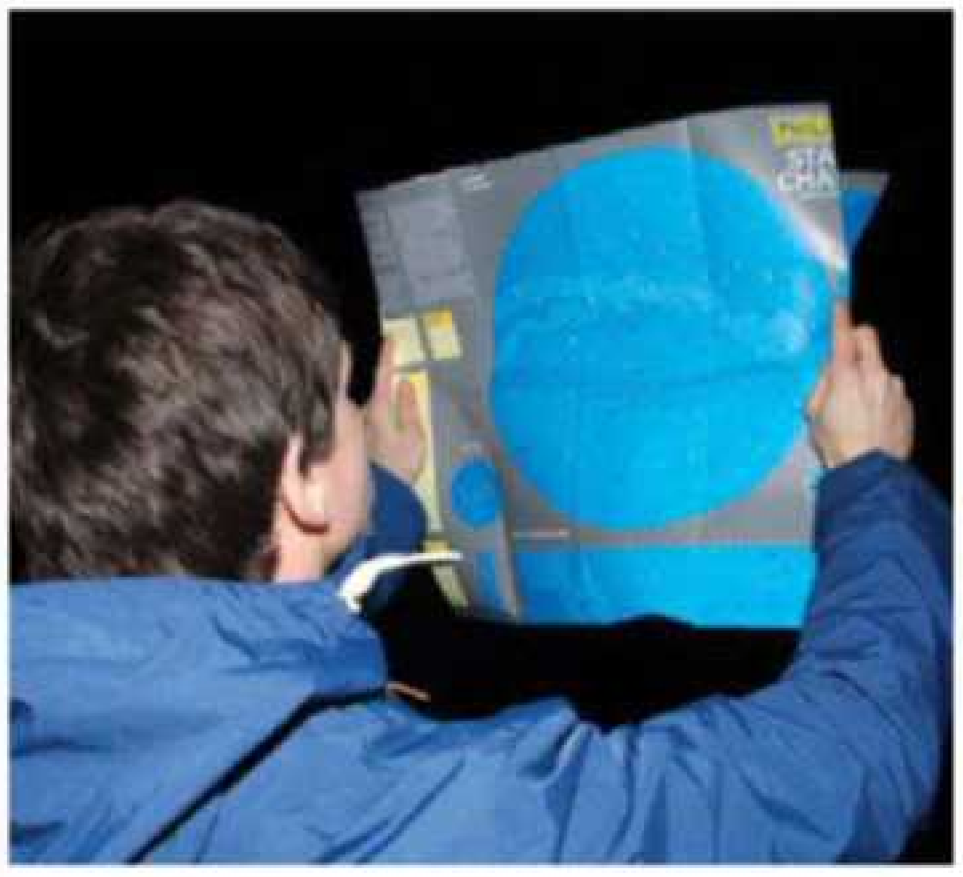
If you're in the northern hemisphere, you'll most likely be familiar with 'the Plough' or 'Big Dipper', a seven-star constellation that belongs to a larger constellation known as Ursa Major, the Great Bear. You might even be able to find and name some famous constellations such as Cancer, Leo or Orion. It is these old friends and their member stars that will act as signposts to help you to find your way around the night sky.

It's incredibly easy to look up at the night sky and feel very overwhelmed, as countless objects seem to sparkle back at you. That's where star hopping comes in. This technique can be a saviour, especially when you've been hunting for a star cluster or nebula for what feels like the whole night! This way of navigating your way around the night sky is very systematic, and once you know how to star hop effectively, you'll be finding targets in no time. In essence, star hopping is 'jumping' from one view to an adjacent view until you find your desired object, be it a galaxy or nebula.

A planisphere is a great tool for familiarising yourself with local skies

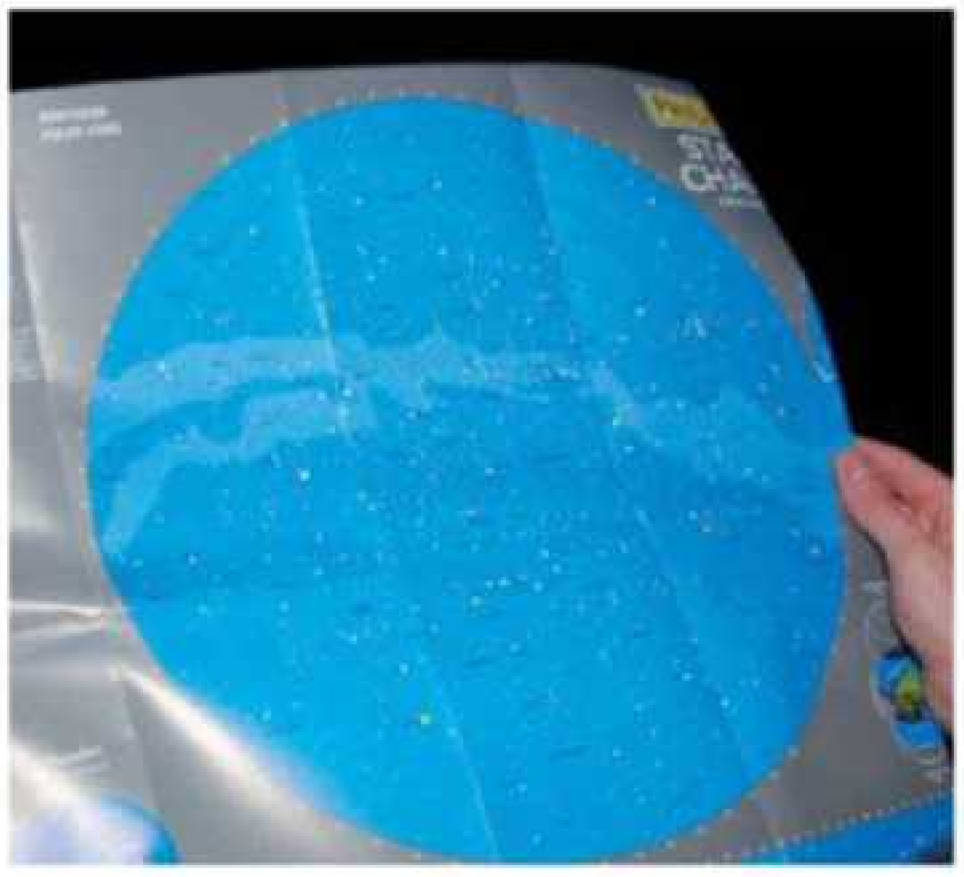
Get out of towns and cities to navigate the night sky more easily

How to use a sky chart



1 Orientation

If you're in the northern hemisphere, you should hold the sky chart or star map above your head pointing south and vice versa for the southern hemisphere. Ensure that you orientate the compass points and use a red light to illuminate it.



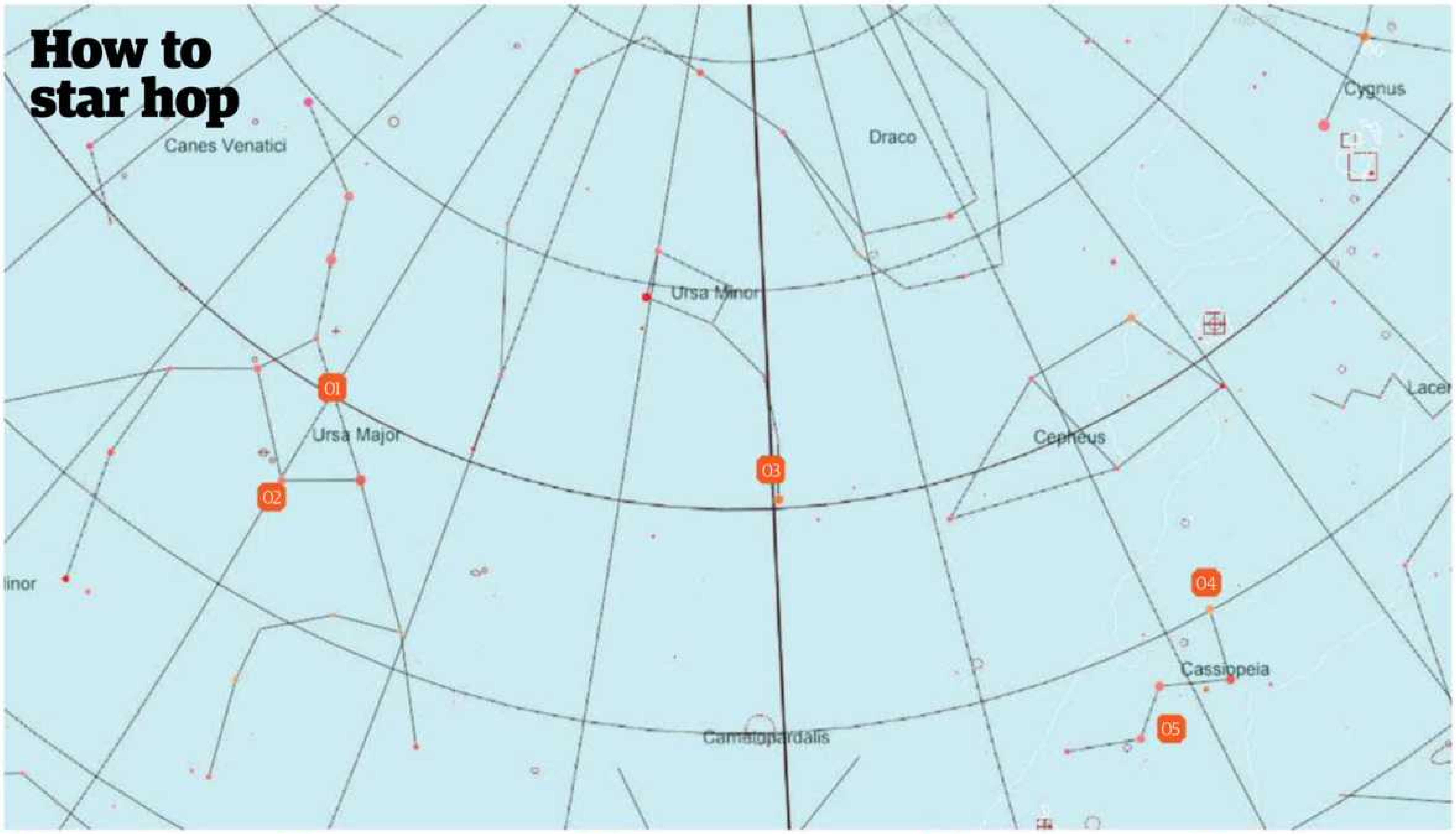
2 Familiarisation

After a few nights of standing under the stars, you'll become more familiar with the constellations. You'll have a dotted line on your map - that's the ecliptic. Close to this line is where the planets and the Moon make their way across the sky.

3 Navigation

Once you have gained a familiarity with the sky, you are now ready to use the star hopping technique shown below: this will enable you to use brighter stars to locate the positions of dimmer and more difficult-to-find objects.

How to star hop



01 Big Dipper

You should easily be able to find the Big Dipper, made of the seven brightest stars in Ursa Major, then locate the bowl-shaped part of it.

02 North Star

Using the two stars that make the lip of the bowl past the Big Dipper, draw an imaginary line upwards. This will get you to the North Star, Polaris.

03 Ursa Minor

Polaris is a star in the constellation, Ursa Minor, which looks like a smaller Big Dipper. Trace the constellation to make sure you're in the right area in the night sky.

04 Cassiopeia

Continue drawing the line you made to Polaris to reach the edge of Cassiopeia, in roughly the same distance.

05 Target constellation

You'll recognise Cassiopeia as a distinctive 'W' shape. Be sure to trace the constellation again so that you can confirm that you're in the right area.

Buying your first telescope

Refractors, reflectors, Dobsonians… **All About Space** takes the guesswork out of finding your perfect stargazing companion

To see the universe at closer quarters, you're going to need a telescope. But choosing one can be a nightmare if you don't know what you're looking for. What's more, you could end up spending hundreds of pounds on an instrument that you either struggle to use and set up or is more geared towards the seasoned astronomer.

A telescope that will do a decent job won't come cheap - you'll probably be looking at somewhere between £150 and £400 ($245 and $655) for a basic but good quality beginners' telescope that comes with at least a couple of eyepieces to get you started. Anything less than £100 ($165), unless it is second-hand, should be approached with caution - especially those found in toy shops or mail-order catalogues, which are usually made of very cheap plastic. Aside from their plastic lenses, they also lack the most important thing you'll need for good stargazing sessions - a decent aperture.

When astronomers talk about aperture, they are referring to the size of the telescope's lens or main mirror, which is essentially the same size as the diameter of the opening of the telescope's tube. The bigger the aperture, the more light that is captured and the fainter and smaller the object you can see.

The minimum aperture you should be looking for is three inches, but you'll be better off with a telescope in the four to six-inch range. With such a telescope you'll be able to see craters and mountains on the Moon, the cloud bands and Great Red Spot on Jupiter, Saturn's rings and a host of star clusters, faint galaxies and diffuse nebulae. Of course, a telescope can only see as well as the quality of the sky it's looking at - so if the sky is lit up by light pollution, you'll see less than you might from a totally dark sky. So try to find an observing spot in your garden facing south, sheltered from nearby street lamps.

Telescopes come in a variety of different types - refractors and reflectors being the main two, and then lots of different versions of each. A refractor uses lenses to bend and focus the light, while a reflector uses two mirrors to direct the light to the eyepiece. Large refractors are more expensive than reflectors of the same size - for around £200 to £300 ($330 to $500) you might get a four-inch refractor, but a five or six-inch reflector. Refractors are great for using high magnification on objects such as planets, where you will want to see small details. Reflectors, on the other hand, are better for pursuing faint objects such as galaxies.

This brings up the issue of magnification. Lots of cheap telescopes claim to have 500x magnification, but if they only have apertures of one or two inches then they are not going to be capturing much light to magnify in the first place, so all you will get is a blurry, unresolved mess when you put your eye to the eyepiece. Get a decent-sized telescope and then apply magnification using different eyepieces carefully, testing the limits of the telescope.

You will also come across jargon such as focal length, or f-ratio. If you know a bit about photography you may have come across these terms before, but how do they apply to telescopes? The focal length is the length of the light's path between the primary mirror or lens and the point where it comes to focus. A refractor with a long focal length has a very long tube, while a reflector can bounce light from one mirror to another, allowing the light path to be 'folded', giving the telescope its 'squashed' appearance. Dividing the focal length by the aperture size gives the f-ratio. Low f-ratios such as f/2 or f/4, which are also described as faster, give larger views through the eyepiece, like you are looking at your target in a huge sea of stars. Fast f-ratios are also preferred by astrophotographers.

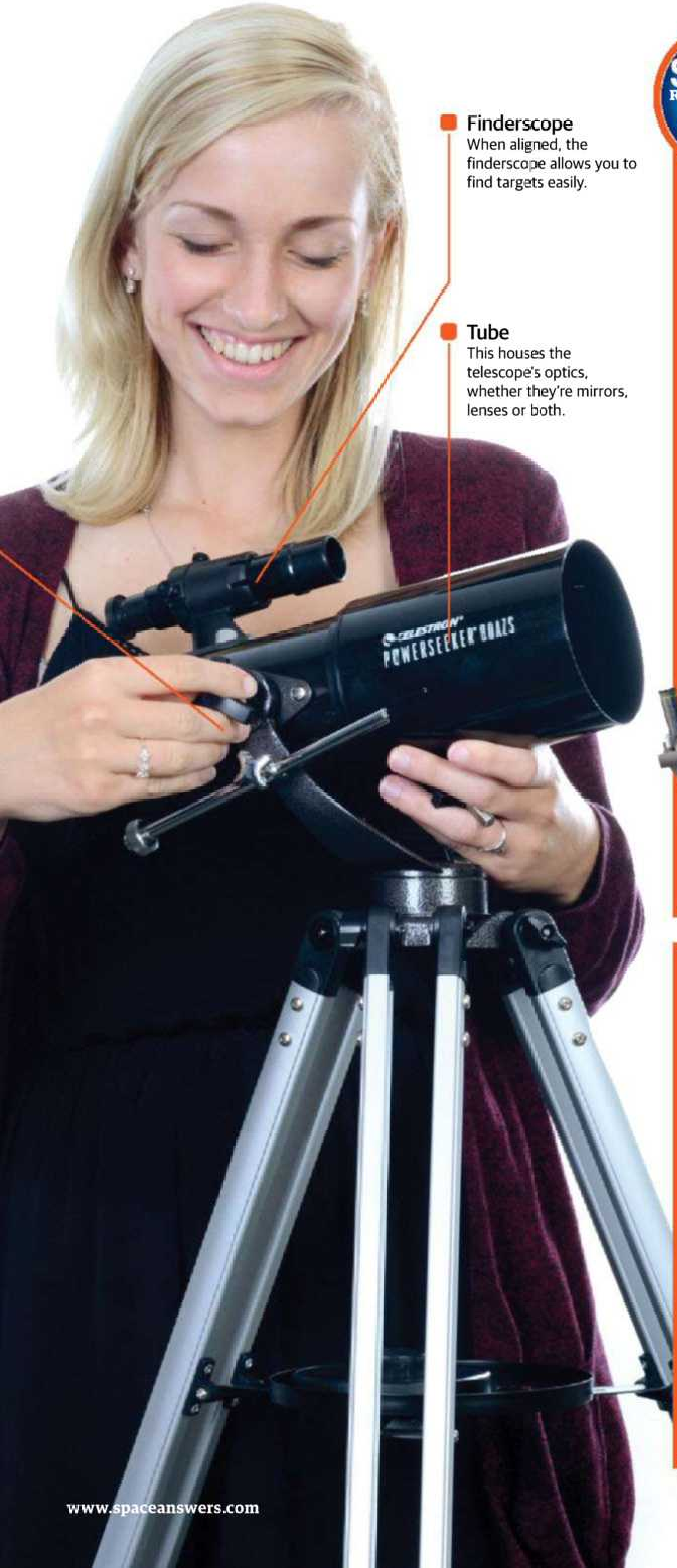
It's also important that you purchase a telescope with a good sturdy tripod to ensure steady views of the night sky as well as a good quality mount capable of holding the telescope tube's weight. While researching your ideal telescope, you'll come across many types of mount, some of which require a hefty counterbalance that often confuses the beginner rather than assists with their tour of the night sky.

The altazimuth mount, which enables the observer to slew their telescope from left to right and up and down, is ideal for beginners. However, if you're looking to splash the cash then a motorised GoTo telescope, which allows you to simply find a target by typing instructions into an attached electronic handset, is often very useful to the novice astronomer. While a bit more expensive than a manual 'scope, it allows the beginner to learn all about the night sky and find targets with ease.

Find your way around a telescope

Focuser
The focuser enables you to fine-tune your view for clear sights of your target.

Eyepiece
Slot in a different eyepiece to boost your telescope's power.


Finderscope
When aligned, the finderscope allows you to find targets easily.
Tube
This houses the telescope's optics, whether they're mirrors, lenses or both.
CELESTRON
POWERSEEKER 80AZS

Telescopes for beginners

Sky-Watcher Evostar-90 AZ3

Cost: £159 (approx. $300)
From: Optical Vision Ltd

With an aperture of 3.5 inches, this refractor is perfect for studying features such as craters and the lunar mare of the Moon, as well as the phases of Venus, the clouds and moons of Jupiter and the rings of Saturn. The Evostar comes with eyepieces of 36x and 90x magnification, a 6x30 finderscope and an altazimuth mount and tripod.

Sky-Watcher Skyliner 200P

Cost: £315 (approx. $515)
From: Optical Vision Ltd

Dobsonian telescopes are reflecting telescopes, built in such a way that you get more aperture - or more light-collecting capabilities - for your money. The Skyliner-200P is an eight-inch telescope and is perfect for soaking up the light from faint fuzzies such as the Andromeda Galaxy. It comes with a connector to attach a DSLR camera and a 9x50 finderscope.

Meade ETX80 tabletop system

Cost: £250 / $299
From: Telescope House / amazon.com

The ETX is Meade's version of the GoTo system but is a straightforward refracting telescope. The tabletop system allows the user to plant the 'scope on a garden table or bench, but there is also a connector for affixing it to a standard photographic tripod. Meade's AutoStar computer GoTo system will take you to over 1,400 objects and includes built-in tours of the night sky.

What makes a good beginner's telescope?

- ✓ Telescopes that come as a complete package - most come with a tripod, finderscope and an eyepiece or two.
- ✓ An instrument that meets your needs - never buy a telescope blindly without doing any research first.
- ✓ The greater the aperture, the better. The larger it is, the sharper and brighter your image will be.
- ✓ Good focal length. Get long focal lengths for high-power objects like the Moon and shorter lengths for taking in larger areas of sky.
- ✓ A steady, sturdy and smoothly working mount.

Which telescopes should I avoid?

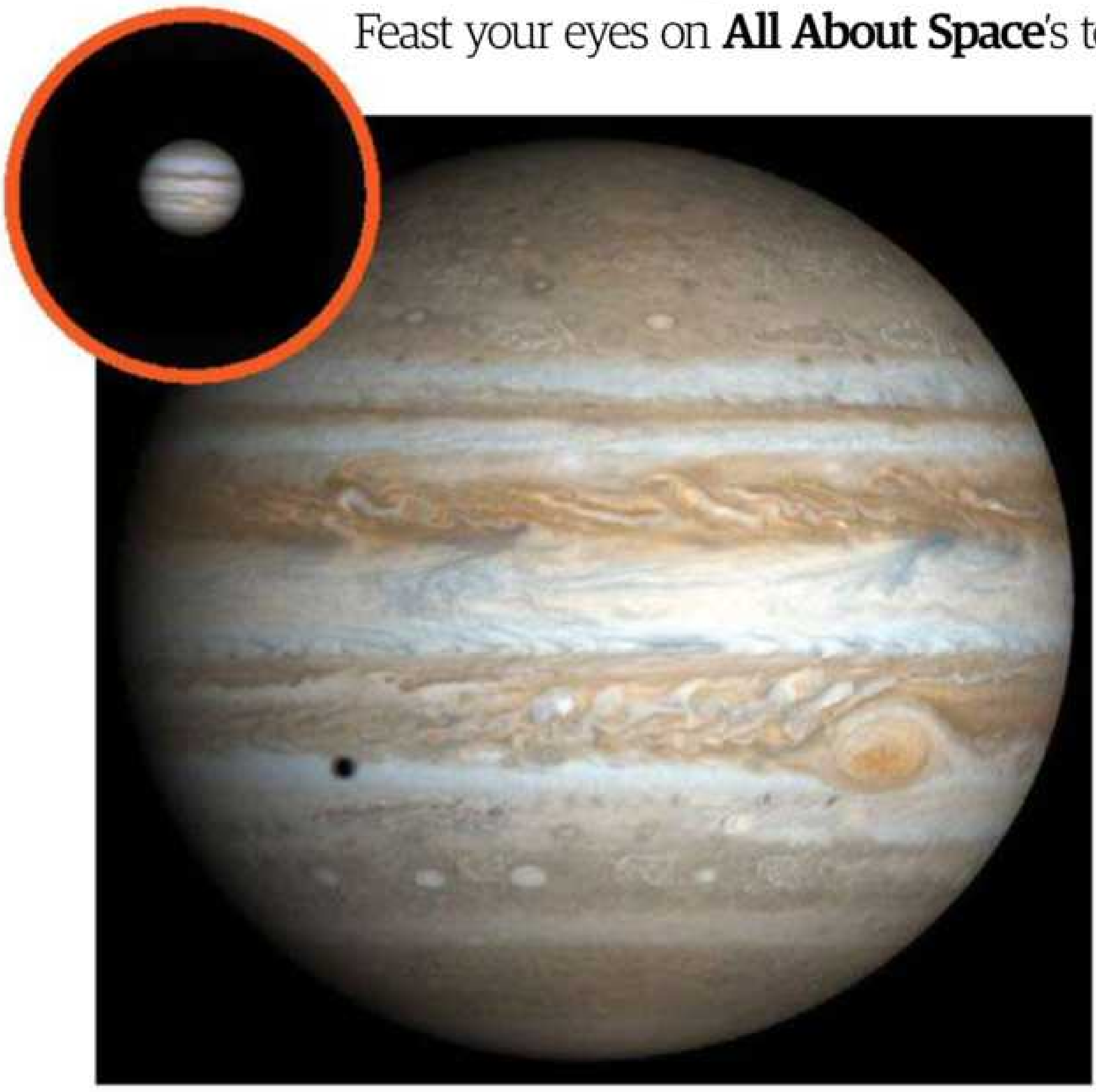
- ✗ Cheap, poor-quality models that you can often find being sold in high-street stores or in mail-order catalogues.
- ✗ Telescopes that are particularly difficult to set up.
- ✗ Instruments that offer fantastic magnification for very little cost - if it sounds too good to be true, then it most probably is.
- ✗ Telescopes that are too heavy for you to carry.
- ✗ A finderscope with a tube hardly thicker than your finger, or that gives a dim, fuzzy view.
- ✗ Instruments that come with eyepieces, with barrels of less than one-and-a-quarter inches.

Meet your top ten targets

Feast your eyes on **All About Space**'s top ten sights for beginners

Key

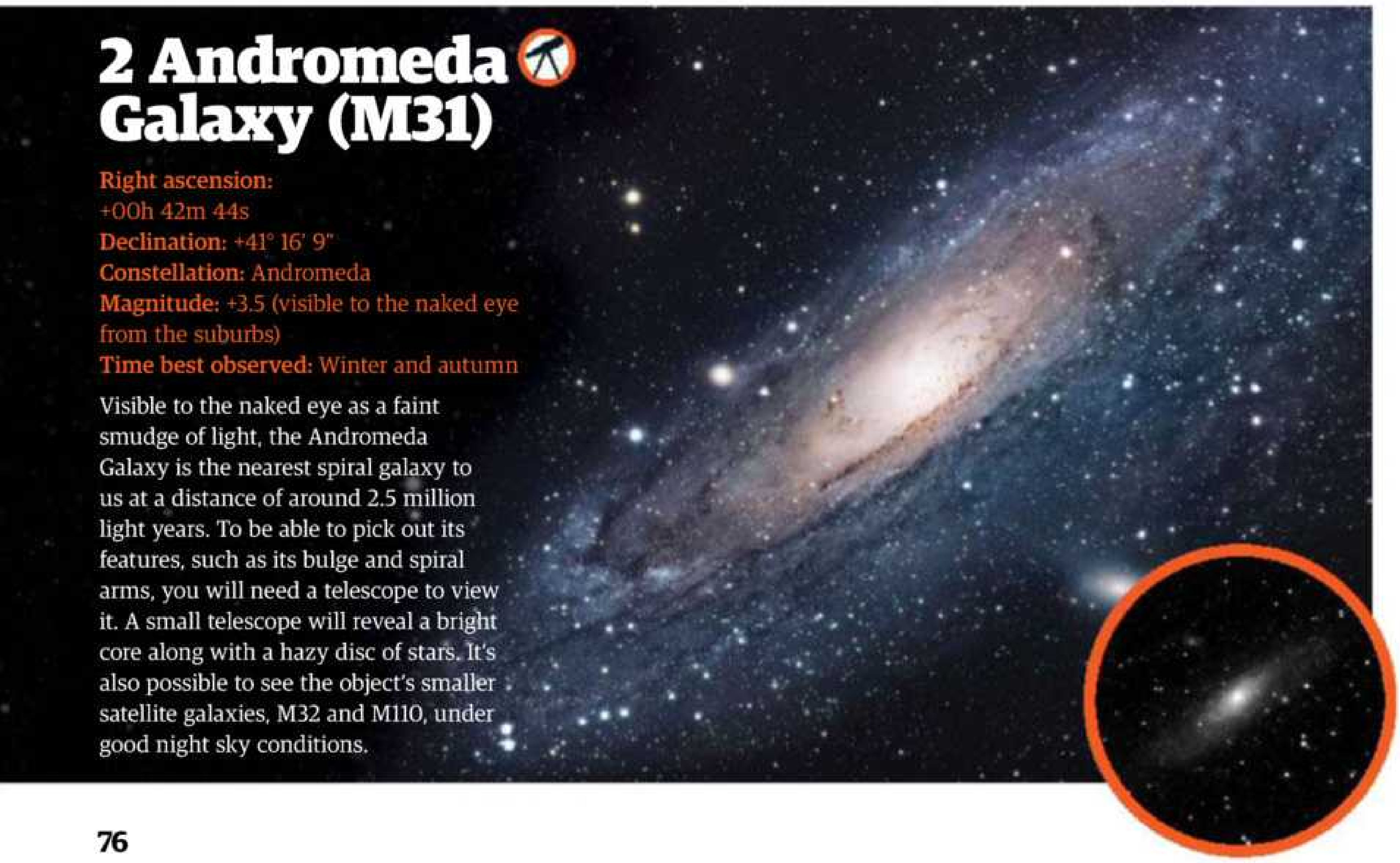
- Naked eye
- Binoculars
- Small telescope
- Medium telescope



1 Jupiter

Right ascension: Varies
Declination: Varies
Constellation: Cancer (at opposition)
Magnitude: -2.6 at opposition (visible to the naked eye everywhere)
Time best observed: Winter

The king of the Solar System, Jupiter will be at its best next February when it reaches opposition - the point at which the planet is at its highest in our sky and at its closest to Earth. During this time, the gas giant is observable for most of the night, where it will be the third brightest object in the night sky after the Moon and Venus. This autumn, the planet is at about magnitude +0.5 and will continue to brighten through to winter. Easily picked out with the naked eye, 10x50 binoculars will reveal the Galilean moons - Io, Europa, Ganymede and Callisto - while a medium-sized telescope will show Jupiter's cloud bands and its famous Great Red Spot.



2 Andromeda Galaxy (M31)

Right ascension: +00h 42m 44s
Declination: +41° 16' 9"
Constellation: Andromeda
Magnitude: +3.5 (visible to the naked eye from the suburbs)
Time best observed: Winter and autumn

Visible to the naked eye as a faint smudge of light, the Andromeda Galaxy is the nearest spiral galaxy to us at a distance of around 2.5 million light years. To be able to pick out its features, such as its bulge and spiral arms, you will need a telescope to view it. A small telescope will reveal a bright core along with a hazy disc of stars. It's also possible to see the object's smaller satellite galaxies, M32 and M110, under good night sky conditions.

3 M81 and M82

Right ascension: +09h 55m 33s
Declination: +69° 3' 55"
Constellation: Ursa Major
Magnitude: +6.9/+8.4
Time best observed: Spring

M81 is one of the best spiral galaxies in the night sky and next-door is the 9th magnitude M82, or Cigar Galaxy. Both are visible in 10x50 binoculars but a medium-sized telescope of around six to eight inches will reveal the winding spiral arms of M81 and its bright core.

4 North America Nebula

Right ascension: +20h 59m 17s
Declination: +44° 31' 44"
Constellation: Cygnus
Magnitude: +4 (visible with the naked eye from dark sites)
Time best observed: Summer

The North America Nebula lies close to Cygnus's brightest star, Deneb. You'll see a dark rift of black dust separating it from the nearby Pelican Nebula. Both are best seen during the summer with a medium-sized telescope and a low magnification eyepiece.

5 Saturn

Right ascension: Varies
Declination: Varies
Constellation: Libra (at opposition)
Magnitude: +0.8 (visible to the naked eye everywhere)
Time best observed: Spring

The ringed planet Saturn is easily spotted with the naked eye as a star-like point, particularly when it is at opposition in May 2015 and in the constellation Libra. You will need a small telescope to pick out the planet's beautiful ring system, which will be tilted towards Earth at an angle of just over 20 degrees. A medium-sized telescope will pick out the enormous gap known as the Cassini Division. Saturn's largest moon, Titan, is fairly easy to find using a small telescope but a good pair of binoculars should also show the satellite from an exceptionally dark site.

6 Orion Nebula (M42)

Right ascension: +05h 35m 17s
Declination: -05° 23' 28"
Constellation: Orion
Magnitude: +4 (visible to the naked eye from the suburbs)
Time best observed: Winter

A great cloud of gas and dust, the Orion Nebula is an area of star formation that rests around 1,300 light years away. It can be found at the tip of the sword hanging from Orion's belt - which is made up of three stars, Alnitak, Alnilam and Mintaka - and is obvious to the naked eye as a fuzzy 'star'. A telescope or pair of binoculars will reveal the nebula's boxy shape and the four brightest stars of the Trapezium Star Cluster, which are just some of the newly formed stellar babies of the nebula.

7 The Pleiades (M45)

Right ascension: +3h 47m 24s
Declination: +24° 7'
Constellation: Taurus
Magnitude: +1.6 (visible to the naked eye from the suburbs)
Time best observed: Winter and autumn

Perhaps one of the more famous star clusters, the Pleiades, also known as M45 or the Seven Sisters, is most obvious to the naked eye during the crisp winter and warmer spring nights. With the unaided eye, most can only see around six to seven of the stars that make a pattern akin to the Plough or Big Dipper constellation - albeit a very small, compact one! However, kicking up the magnification through binoculars or a telescope will reveal dozens more stars.

8 NGC 869 and NGC 884

Right ascension: +2h 20m
Declination: +57° 08'
Constellation: Perseus
Magnitude: +3.8
Time best observed: Autumn

The two great star clusters NGC 869 and NGC 884 are together known as the Double Cluster, and make for an excellent treat on the eyes during the season of autumn, resting high up in the sky in the east. To the naked eye, the Double Cluster is just visible as a fuzzy smudge of diffuse light, while in binoculars or a small telescope, your field of view will be dominated by stars glowing in a stunning variety of colours. These cover an area equal to the size of the Moon - around half a degree of the sky, an area your extended little finger would cover.

9 M13

Right ascension: +16h 41m 41s
Declination: +36° 27' 36"
Constellation: Hercules
Magnitude: +5.8 (just about visible to the naked eye from the darkest sites)
Time best observed: Spring and summer

The most striking globular cluster in the northern sky, M13 is best viewed during the spring through to early summer in the constellation of Hercules. Pleasing sights can be had using a small telescope but to really make M13's stellar population pop, then a four-inch telescope with a magnification of 120x is recommended.

10 Mizar and Alcor

Right ascension: +13h 23m 55s/ +13h 25m 13s
Declination: +54° 55' 31"/ +54° 59' 17"
Constellation: Ursa Major
Magnitude: +2.2/+4.0 (visible to the naked eye from the suburbs)
Time best observed: Spring

For many people, Mizar and Alcor will be the first time they see a double star system. Look along the handle of the Plough in Ursa Major and gaze carefully at the second star from the end. If you have relatively good eyesight, you'll notice that what appears at first glance to be one star is actually two. The brightest, at a magnitude of +2.2 is Mizar while the fainter star is Alcor. Turn a telescope to Mizar and you'll quickly see that it's another double star!

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20 targets for light-polluted sky

Living in a town or city? Never fear, we've got the ideal astronomical targets for you to observe

You've checked the weather forecast and you've got the clearest of skies ready for the meteor shower that's set to turn up. There's no Moon, providing you with the ideal opportunity to catch these chunks of space rock, which burn up in the Earth's atmosphere to give them their characteristic glow.

Wrapped up in your woolly hat, scarf and gloves you head outside but stop in your tracks. Just outside your front door, there's an orange haze. A newly installed street lamp flicks on for the night. You try to make out the constellation that your night sky guide says the meteors are meant to be hailing from, but it's impossible to see, so you head back inside. This is the scourge of light pollution - something astronomers loathe, due to its often unstoppable ability to obscure the beauty of the night sky. You might be someone who lives in a town, a city or perhaps a less-populated village near street lamps lighting up your street. If you do, you might think that you can't do any astronomy and you'll never get to see any of the wonders that pepper the universe. That is, unless you move to a darker location.

While the best astronomy is done under the darkest of skies and during the winter months, you would be forgiven for thinking that *no* astronomy can be done under heavens tinged with light pollution. With a pair of binoculars, a telescope or even your naked eye, however, you can certainly beat it - and **All About Space** shows you how with our top 20 targets. Don't forget to check out our top ten targets for beginners on page 76, some of which can also be seen in light-polluted skies.

"With the right equipment you can beat light pollution"

5 top tips for stargazing from light-polluted areas

1. Shield your optics

Shielding the equipment you are using can work wonders in stopping stray light from entering. If you have a short dew shield on your telescope, then it can be extended using thick, black card. Alternatively, flexible 'wings' can be bought from reputable dealers to shade your telescope or binoculars.

2. Use specialist filters

Coloured filters, which enhance details on objects such as the Moon and planets, are also very helpful in reducing light pollution. Specialist filters, such as City Light Suppression (CLS) or Anti Light Pollution (ALP) filters, are able to tune out wavelength emitted by low-pressure sodium streetlight.

3. Try astrophotography

Manipulating images using appropriate photography software can help to eliminate the effects of light pollution by reducing the orange glow of city lights. Of course this option can work out to be quite expensive if you don't already own a DSLR or CCD camera, though.

4. Stay out late

Stray light reduces as the night wears on - particularly after or around midnight. You'll find that your neighbours turn their lights off both inside and outside their houses and many local authorities will also turn their street lighting off after midnight. This will contribute to the lower light levels.

5. Watch the weather

Artificial light shines into the sky and is reflected back down by dust and water vapour in the air. When there's high humidity or very dry spells then dust can easily be thrown into the atmosphere, making things worse. Wait for stable conditions with low wind speeds.

TURN OVER TO SEE OUR TOP 20 CITY NIGHT SIGHTS...

1 The Moon

Best seen: All year
Magnitude: -12.7 (full Moon)
Minimum aid: Naked eye

A familiar sight in the night sky, the Moon serves as an excellent target in light-polluted areas. Even in well-lit regions, lunar mare and craters can easily be picked out with the naked eye while binoculars and telescopes will pick out the detail of smaller impacts and mountains.

2 Venus

Best seen: June 2015
Magnitude: +5.0
Minimum aid: Naked eye

Venus will reach greatest elongation east at the beginning of June next year, hitting a brightness of +5.0 and making the planet unmistakable in the evenings. Easily a naked-eye target, better views of the second planet from the Sun can be obtained using a pair of binoculars or a telescope. To see the terrestrial planet's phases, the larger the power of your telescope, the better.

3 NGC 2903

Best seen: Winter
Magnitude: +9.7
Constellation: Leo
Right ascension: 09h 32m 10.1s
Declination: +21° 30' 03"
Minimum aid: Small telescope

NGC 2903 is one of the brighter galaxies seen from the northern hemisphere and your best bet for picking out this winter gem is to use at least a small telescope. However, if you have a pair of binoculars, greater in magnification than 10x50, then this spiral galaxy and its exceptional rate of star formation can be picked out under light-polluted skies.

4 Sirius

Best seen: Winter
Magnitude: -1.46
Constellation: Canis Major
Right ascension: 06h 45m 09s
Declination: -16° 42' 58"
Minimum aid: Naked eye

Sirius is the brightest star in the night sky and can be found in its full glory during the winter months by following an imaginary line from Orion's belt down to the left. It is a binary star system made up of a main sequence and a white dwarf star in orbit around each other. Even in light-polluted skies Sirius can be separated into its two components using a telescope.

5 Sculptor Galaxy (NGC 253)

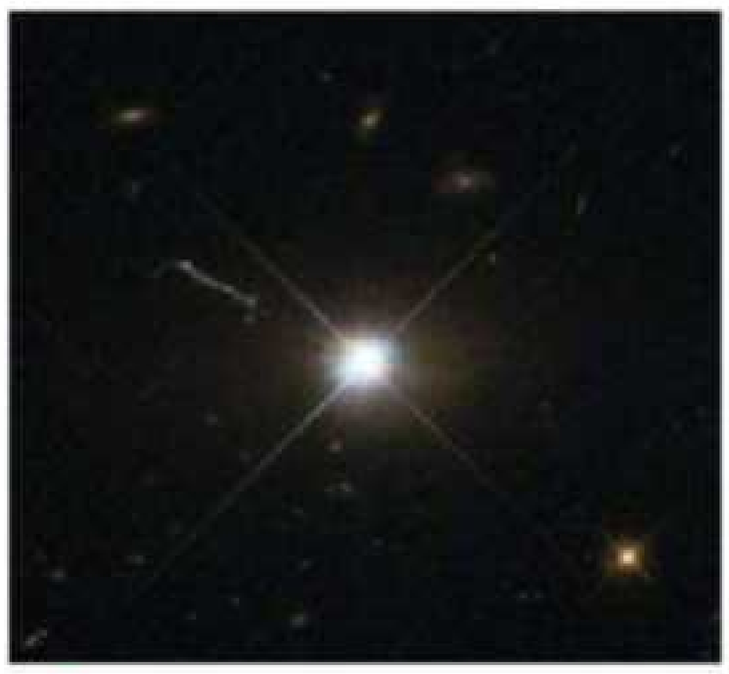
Best seen: Autumn
Magnitude: +8.0
Constellation: Sculptor
Right ascension: 00h 47m 33s
Declination: -25° 17' 18"
Minimum aid: 10x50 binoculars

Also known as the Silver Coin or Silver Dollar Galaxy, the Sculptor Galaxy is at its finest during the autumn months and can be picked out quite easily in light-polluted areas by simply using a decent pair of binoculars. One of the most easily viewed galaxies after Andromeda, NGC 253 also makes for fair game in telescopes where a long and bright oval bulge can be picked out surrounded by a disc of dust and gas.

6 Messier 96

Best seen: Winter
Magnitude: +10.1
Constellation: Leo
Right ascension: 10h 46m 45.7s
Declination: +11° 49′ 12″
Minimum aid: Large telescope

Quite easy to locate in the belly of the constellation of Leo, Messier 96 is viewable using a large pair of binoculars under very good viewing conditions. However, in areas of light pollution, the spiral galaxy is perceivable in a small telescope - but only just. Larger apertures are a must in order to bring out details of the galaxy's arms on a Moonless night.



8 3C 273

Best seen: Spring
Magnitude: +12.9
Constellation: Virgo
Right ascension: 12h 29m 06.7s
Declination: +02° 03′ 09″
Minimum aid: Large telescope

Best observed during spring and in particular May in both the northern and southern hemispheres, 3C 273 - which is not only one of the most luminous quasars known but also happens to hold the title of being the first quasar ever identified - shines at a magnitude of around +13. Turning a large-aperture telescope towards its location in the constellation of Virgo, however, will provide you with views of a point-like source not too dissimilar to a star.

9 Mars

Best seen: 22 May 2016
Magnitude: -2.0
Constellation: Scorpius
Minimum aid: Naked eye

Next reaching opposition in 2016, when the Red Planet will be at its best during the night skies of May, Mars is easily picked out with the naked eye as a red 'unblinking' star. Binoculars will show the fourth planet from the Sun up as a salmon-pink disc, while medium to large telescopes should help to reveal some of Mars's most interesting surface features. Remember, though, that the use of filters and good night sky conditions will provide you with optimum views of the Red Planet.

7 Lagoon Nebula (Messier 8)

Best seen: Summer
Magnitude: +6.0
Constellation: Sagittarius
Right ascension: 18h 03m 37s
Declination: -24° 23′ 12″
Minimum aid: 10x50 binoculars

A target in clear night skies untouched by light pollution, the Lagoon Nebula can be picked up in the constellation of Sagittarius with the naked eye. However, unless you have exceptional eyesight, this emission nebula is best found using a pair of binoculars or a telescope. Using a minimum optical aid, Messier 8 takes on a distinct cloud-like oval. As with any nebula, you'll see much more with a greater aperture and filters.

10 Omega Nebula (Messier 17)

Best seen: Summer
Magnitude: +6
Constellation: Sagittarius
Right ascension: 18h 20m 26s
Declination: -16° 10′ 36″
Minimum aid: 10x50 binoculars

Appearing similar in size to an 'edge-on' Orion Nebula, Messier 17 can be found in the rich starfields of the Sagittarius constellation. Also dubbed the Swan or Horseshoe Nebula, it can be found quite easily using binoculars. Alternatively, if you happen to be under exceptionally dark summer skies, then this diffuse nebula is easy to trace using the naked eye. Larger telescopes will also reveal just over 30 stars embedded in the nebulosity.

11 Betelgeuse

Best seen: Winter
Magnitude: +0.42
Constellation: Orion
Right ascension: 05h 55m 10.3s
Declination: +07° 24′ 25.4″
Minimum aid: Naked eye

12 Hyades

Best seen: Autumn
Magnitude: +0.5
Constellation: Taurus
Right ascension: 4h 27m
Declination: +15° 52′
Minimum aid: Naked eye

13 Sagittarius Star Cloud (Messier 24)

Best seen: Summer
Magnitude: +4.6
Constellation: Sagittarius
Right ascension: 18h 17m
Declination: -18° 29′
Minimum aid: 10x50 binoculars

14 Messier 92

Best seen: Spring
Magnitude: +6.3
Constellation: Hercules
Right ascension: 17h 17m 07.4s
Declination: +43° 08′ 09.4″
Minimum aid: 10x50 binoculars

15 Messier 41

Best seen: Winter
Magnitude: +4.5
Constellation: Canis Major
Right ascension: 06h 46m
Declination: -20° 46′
Minimum aid: 10x50 binoculars

16 Messier 22

Best seen: Summer
Magnitude: +5.1
Constellation: Sagittarius
Right ascension: 18h 36m 23.9s
Declination: -23° 54′ 17.1″
Minimum aid: 10x50 binoculars

17 Virgo A

(Messier 87)

Best seen: Spring
Magnitude: +9.59
Constellation: Virgo
Right ascension: 12h 30m 49.4s
Declination: +12° 23′ 28″
Minimum aid: Small telescope

An almost featureless ellipsoid with no dust lanes to speak of, Messier 87 might not be as visually impressive as the majestic spiral galaxy, but being the second brightest galactic structure of the Virgo Cluster and home to a supermassive black hole makes it a popular target among amateur astronomers. A large galaxy, Messier 87 is readily picked up using a small telescope, but light pollution may force you to upgrade to a medium-sized 'scope in order to find it.

The Campaign for Dark Skies

Light pollution is a big problem for many astronomers. That's why the Campaign for Dark Skies (CfDS) was founded by a group of amateur astronomers in 1989 and is currently run by the British Astronomical Association (BAA). Open for everyone to join, the CfDS is trying to reduce lighting where appropriate and helped to establish several Dark Sky Parks and Reserves.

18 Messier 65

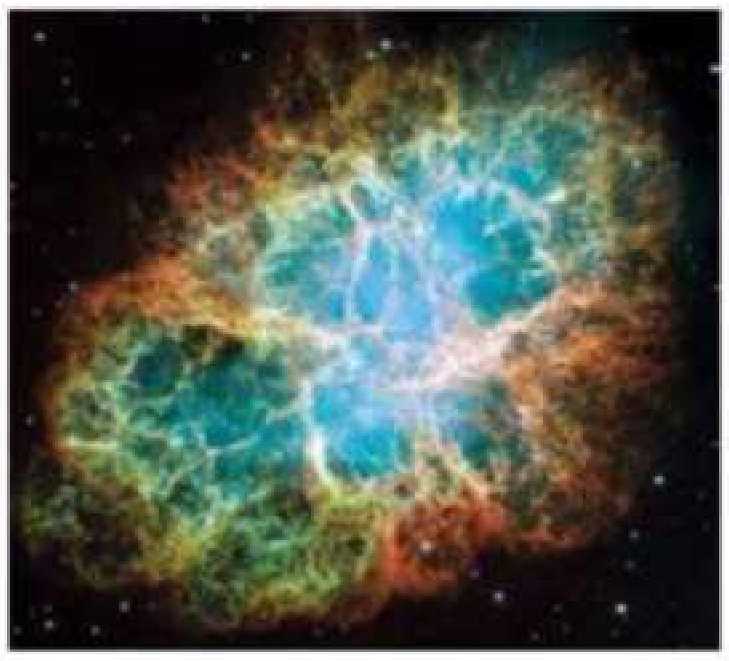
Best seen: Winter
Magnitude: +10.25
Constellation: Leo
Right ascension: 11h 18m 55.9s
Declination: +13° 05′ 32″
Minimum aid: Small telescope

Located around 35 million light years away and a member of the 'Leo Triplet', which also contains Messier 66 and NGC 3628, Messier 65 (also known as NGC 3623) can often be found using a pair of binoculars as a distinct grey oval. If you find yourself battling against moonlight and/or light pollution, however, you are likely to struggle without the improved aperture of a telescope capable of teasing out the structure of this wonderful spiral.

19 Dumbbell Nebula (Messier 27)

Best seen: Summer
Magnitude: +7.5
Constellation: Vulpecula
Right ascension: 19h 59m 36.34s
Declination: +22° 43′ 16.09″
Minimum aid: 10x50 binoculars

A picture of a star death in action, with hot material being thrown out from an extremely intense stellar core, the Dumbbell Nebula will appear as a large star that seems fuzzy and out of focus. Of course, the power of a telescope will reveal more and you should be able to pick out this planetary nebula's central star. Due to its diffuse nature, you will receive pleasing views with the assistance of filters to play up the nebula's beautiful colours.



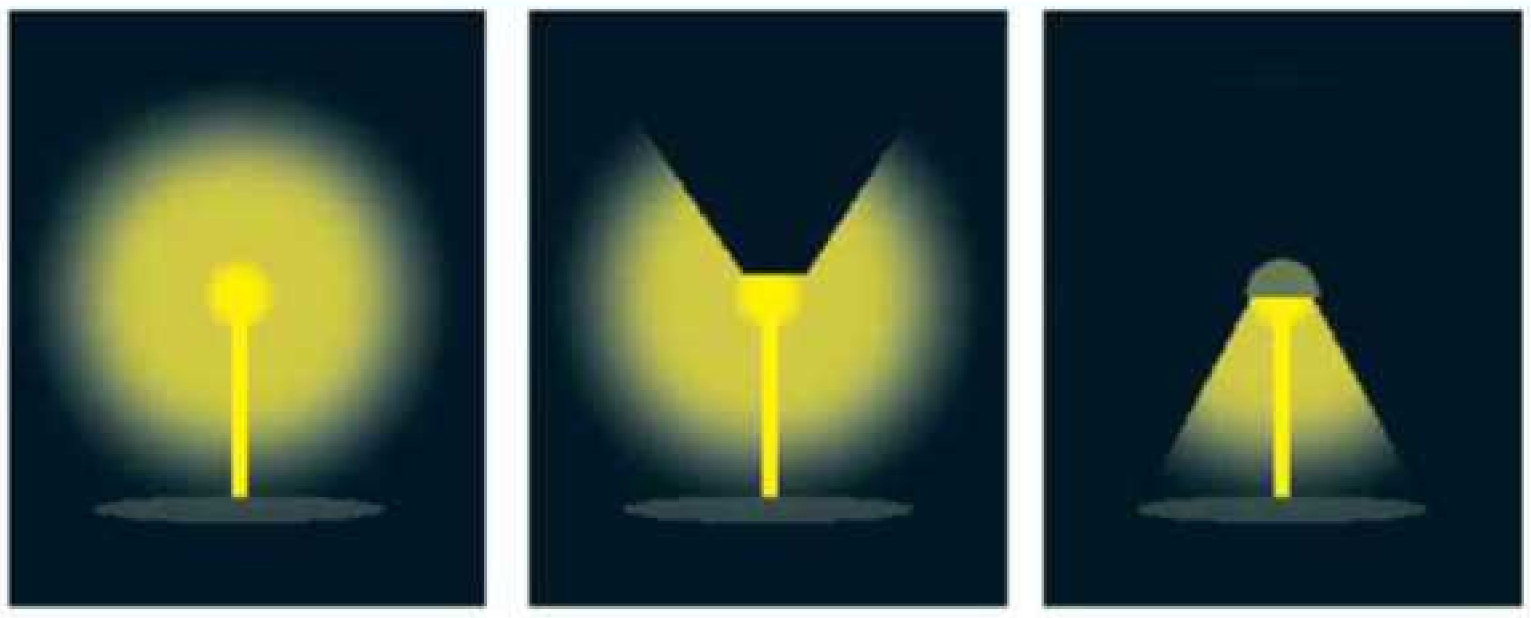
20 Crab Nebula (Messier 1)

Best seen: Autumn
Magnitude: +8.4
Constellation: Taurus
Right ascension: 05h 34m 31.94s
Declination: +22° 00′ 52.2″
Minimum aid: Medium telescope

Easily one of the most famous supernova remnants in the night sky, the Crab Nebula is the aftermath of the catastrophic explosion of a star that went supernova in 1054. Not visible to the naked eye even under the most favourable of conditions, Messier 1 requires a telescope to be seen from towns in its faint and fuzzy form. With a very good telescope and imaging equipment, you can draw out the breathtaking detail of this object.

All about streetlights

Street lights are expensive and the authorities will place them only where needed. But just by altering the direction of artificial light and changing the usual yellow, sodium lamps, 'cooler' white light sources such as LEDs can work wonders in preserving dark skies.



Very bad

Better

Best

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What's in the sky?

All seasons change for both hemispheres, as dark skies lengthen in the north and the south creeps towards a long summer

Jupiter

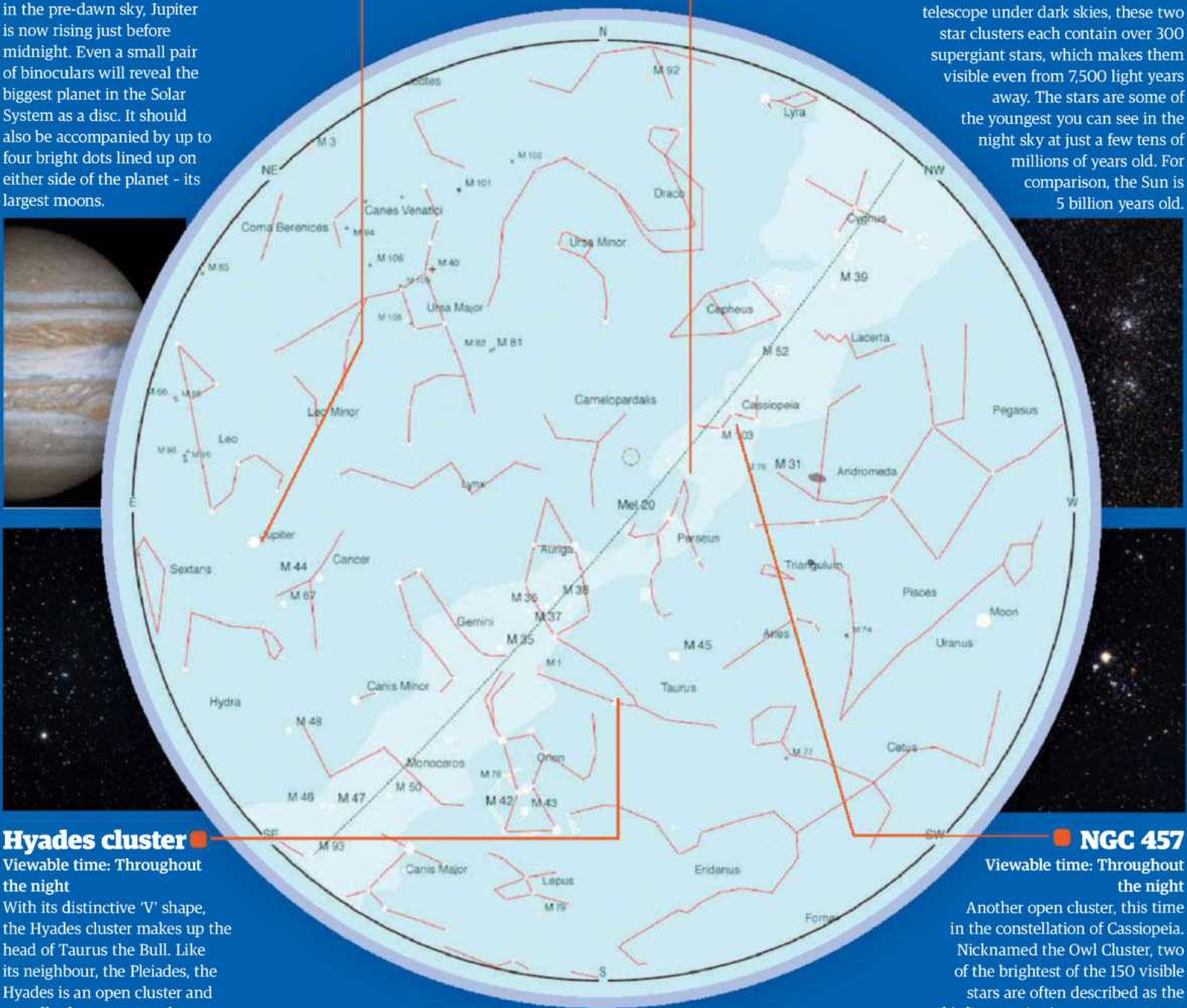
Viewable time: After midnight

After spending the past few months cosying up to Venus in the pre-dawn sky, Jupiter is now rising just before midnight. Even a small pair of binoculars will reveal the biggest planet in the Solar System as a disc. It should also be accompanied by up to four bright dots lined up on either side of the planet - its largest moons.

Perseus double cluster

Viewable time: Throughout the night

Often visible without binoculars or a telescope under dark skies, these two star clusters each contain over 300 supergiant stars, which makes them visible even from 7,500 light years away. The stars are some of the youngest you can see in the night sky at just a few tens of millions of years old. For comparison, the Sun is 5 billion years old.



Hyades cluster

Viewable time: Throughout the night

With its distinctive 'V' shape, the Hyades cluster makes up the head of Taurus the Bull. Like its neighbour, the Pleiades, the Hyades is an open cluster and actually the nearest such group to the Solar System. The brightest star in this region is Aldebaran but it isn't actually part of the cluster, instead lying closer to us.

Northern hemisphere

NGC 457

Viewable time: Throughout the night

Another open cluster, this time in the constellation of Cassiopeia. Nicknamed the Owl Cluster, two of the brightest of the 150 visible stars are often described as the bird's eyes. Again very young stars - around 20 million years old - they sit almost 8,000 light years from us and were discovered by William Herschel in 1787.

Pleiades

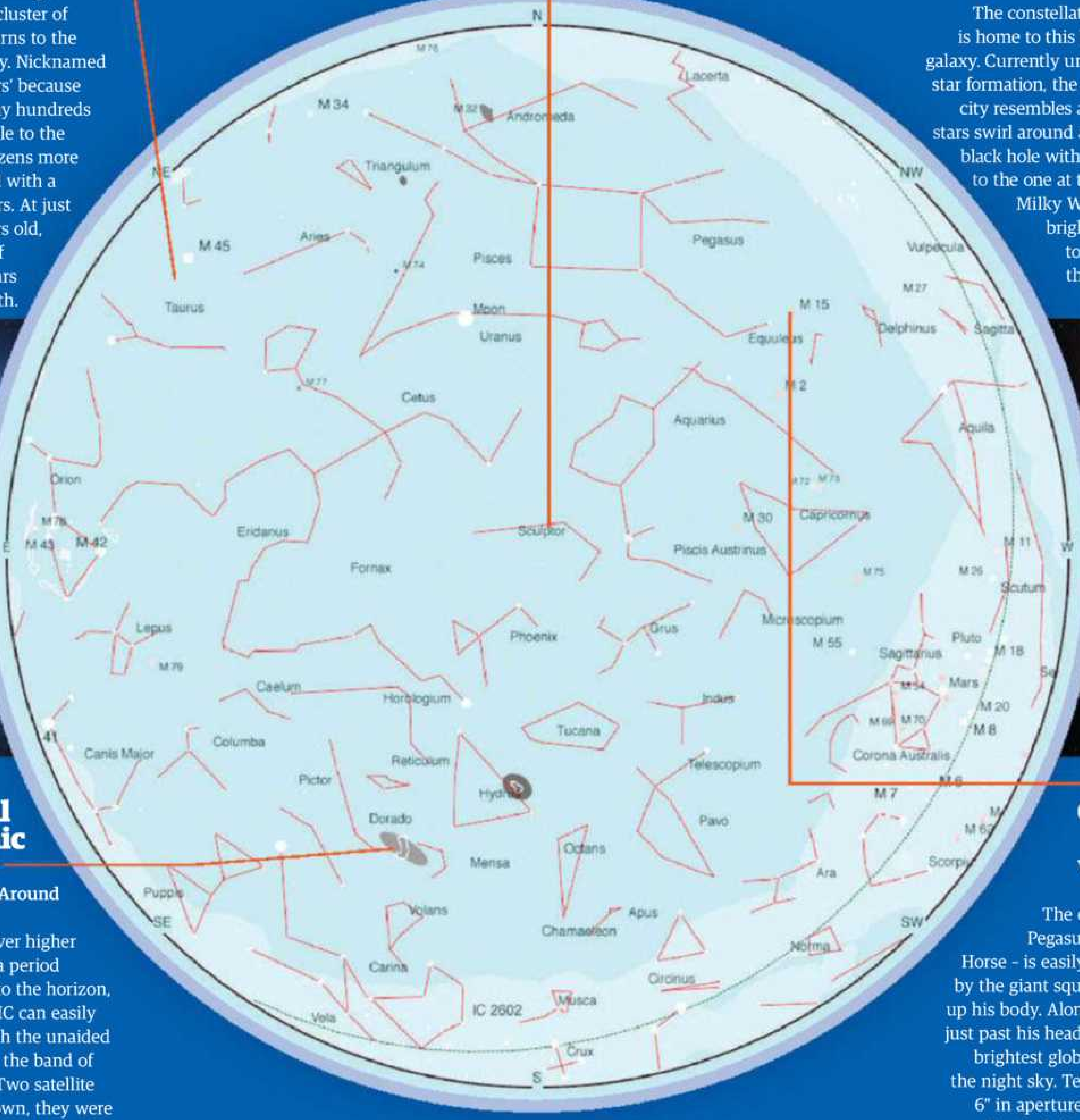
Viewable time: After 10pm

Heralding the coming of year's end, this cluster of young stars returns to the pre-midnight sky. Nicknamed the 'Seven Sisters' because seven of its many hundreds of stars are visible to the unaided eye, dozens more can be glimpsed with a pair of binoculars. At just 100 million years old, they are some of the youngest stars visible from Earth.

Sculptor Galaxy

Viewable time: Throughout the night

The constellation of Sculptor is home to this beautiful spiral galaxy. Currently undergoing rapid star formation, the disc of the star city resembles a silver coin. Its stars swirl around a supermassive black hole with a similar mass to the one at the heart of the Milky Way. Particularly bright, it is possible to see the galaxy through a pair of binoculars.



Southern hemisphere

Large and Small Magellanic Clouds

Viewable time: Around 9pm onwards

Now climbing ever higher in the sky after a period sweeping close to the horizon, the LMC and SMC can easily be made out with the unaided eye not far from the band of the Milky Way. Two satellite galaxies of our own, they were first reported to westerners by Ferdinand Magellan in the early 16th Century.

M15 Globular Cluster

Viewable time: Before 10pm

The constellation of Pegasus - the Winged Horse - is easily distinguished by the giant square that makes up his body. Along his neck and just past his head lies one of the brightest globular clusters in the night sky. Telescopes above 6" in aperture will be able to resolve individual members of this ancient collection of over 100,000 stars.

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Me & My Telescope

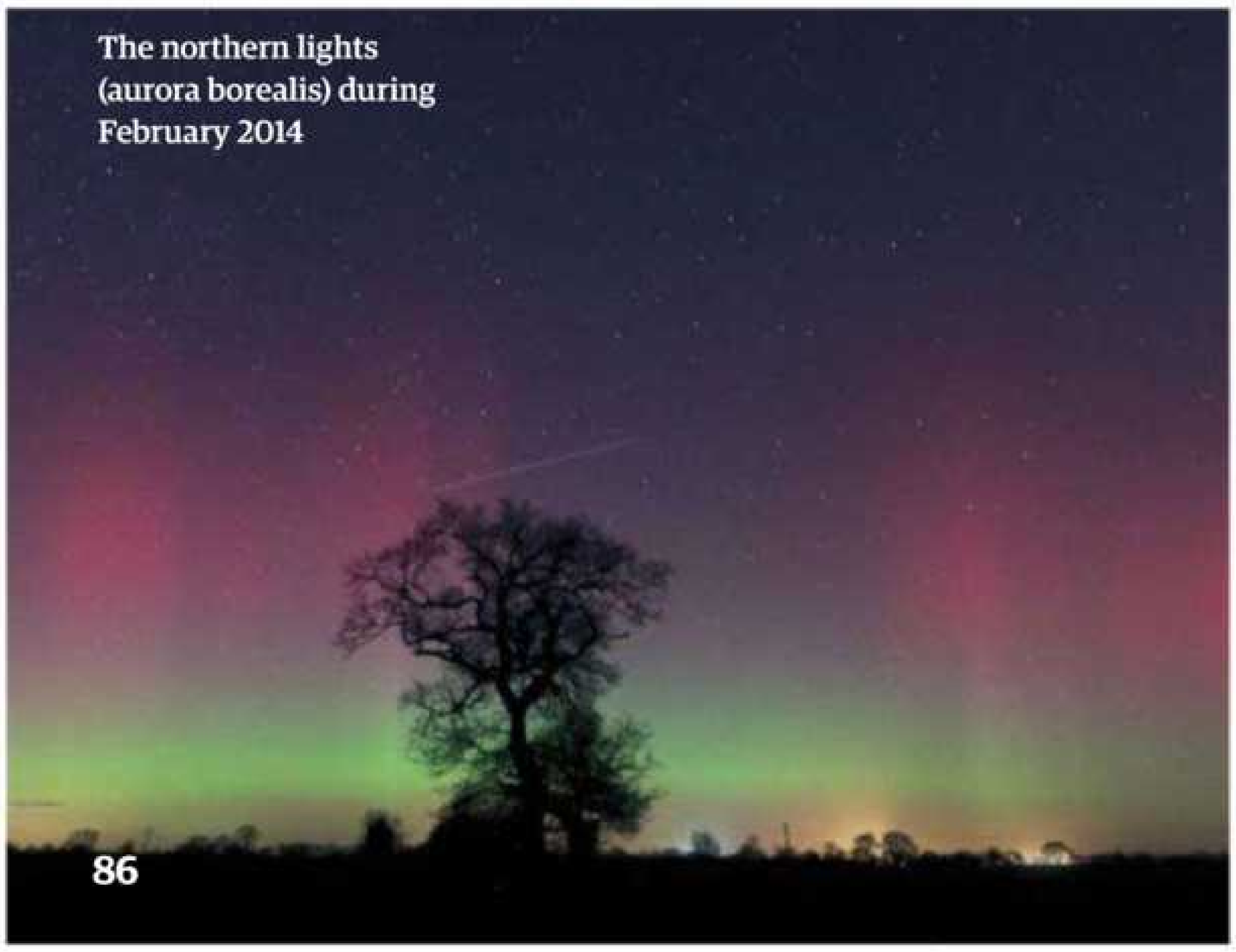
Send your astronomy photos and pictures of you with your telescope to **photos@spaceanswers.com** and we'll showcase them every issue

Wendy Clark

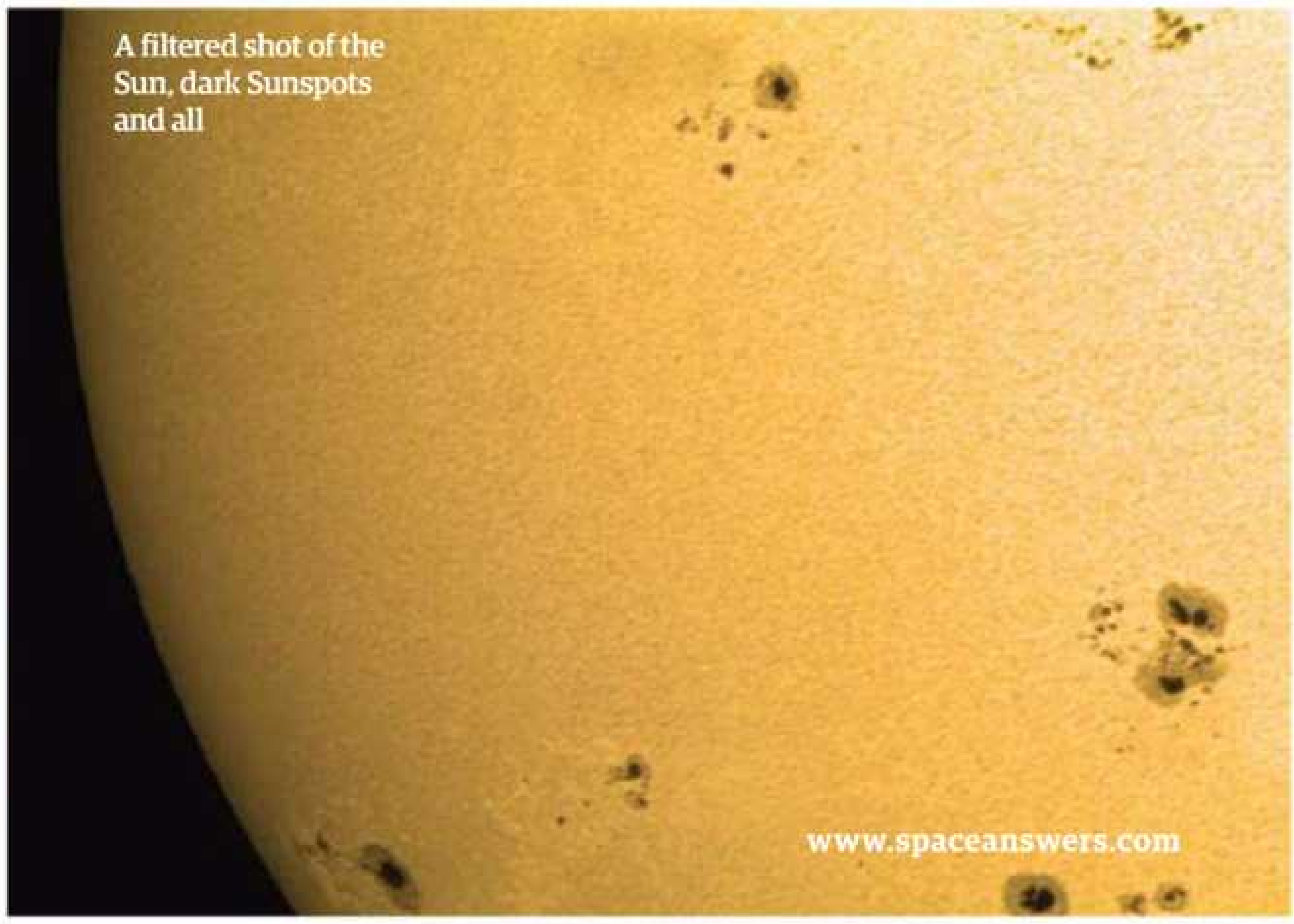
Essex, UK

Telescope: Sky-Watcher 120ED Esprit & Orion StarShoot Autoguider

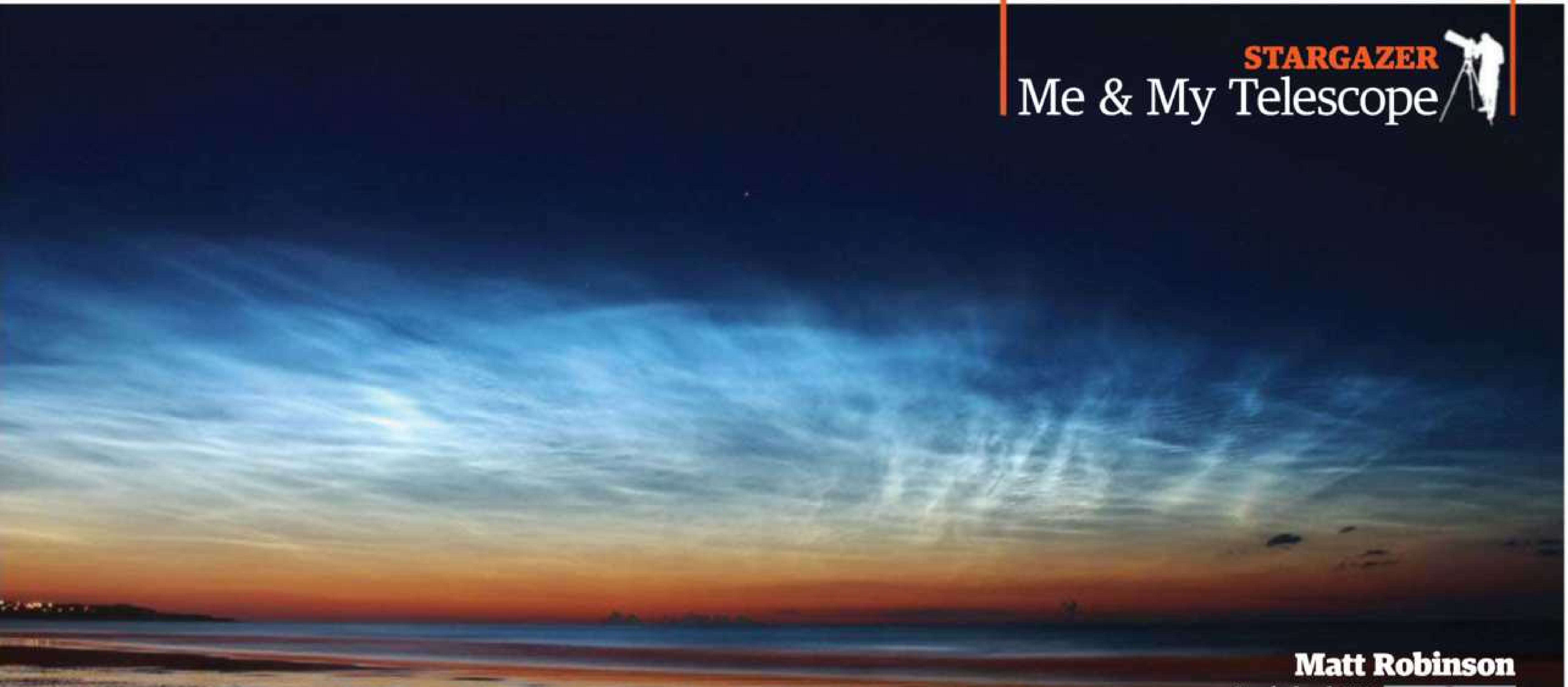
"The late Sir Patrick Moore's *Sky At Night* led to my interest in astronomy as a child. It wasn't until 2004 that I ended up with a basic 3" telescope on an equatorial mount. There were no counterweights to balance any additional camera equipment, resulting in a lot of afocal Moon shots. Up until 2013, I used a Canon 350D but now I use a Canon 700D camera with a 10-22mm or 70-300mm lens. I love using my Sky-Watcher 120ED - the clarity is amazing."



The northern lights (aurora borealis) during February 2014



A filtered shot of the Sun, dark Sunspots and all



Matt Robinson

Sunderland, UK

Telescope: Sky-Watcher Heritage-130P

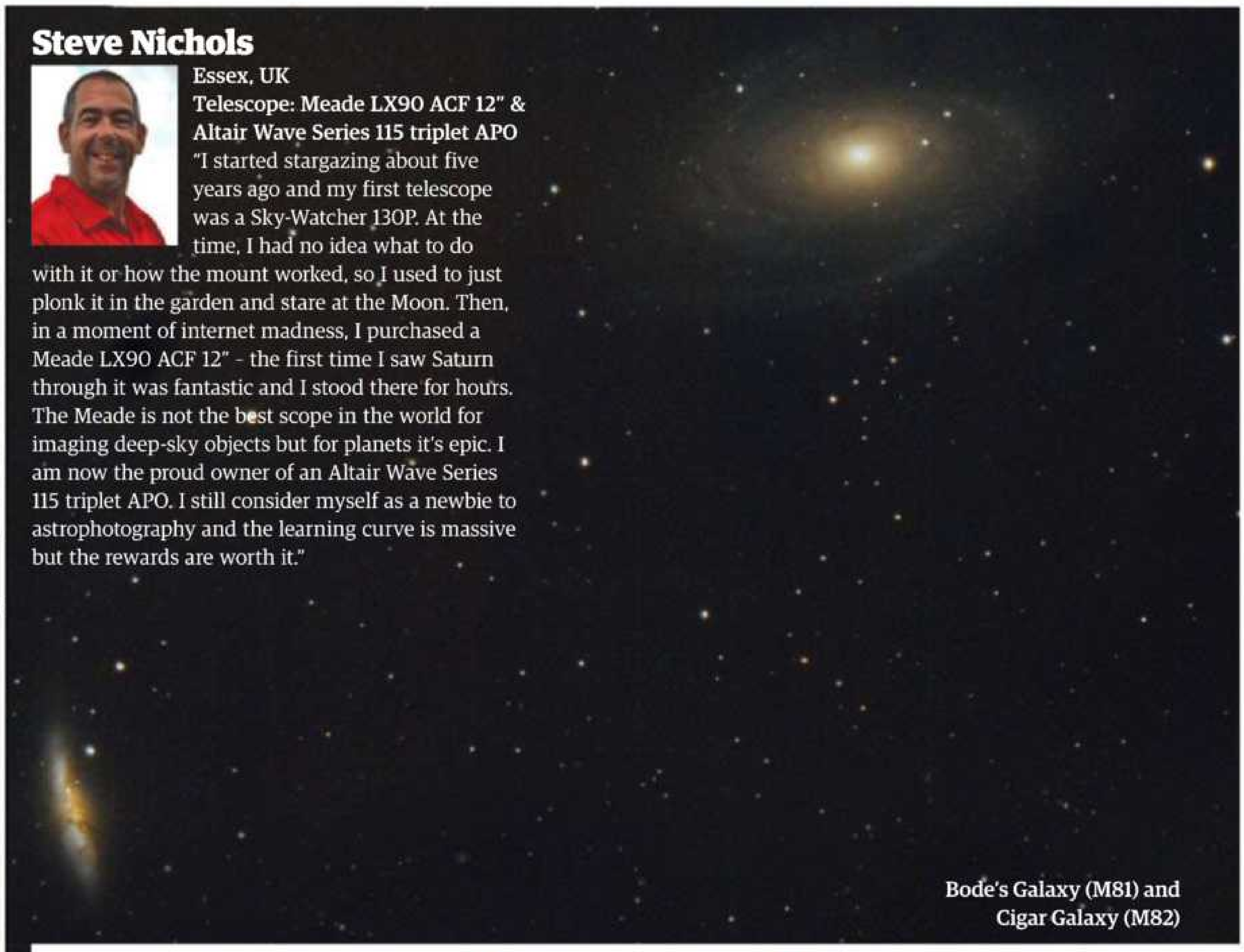
"I have been an amateur astronomer for three years and developed the astronomy bug from observing the Orion Nebula. I started asking myself why it appears the way it does. Since then I have started volunteering at Kielder Observatory in the Northumberland International Dark Sky Park. I shot noctilucent clouds using a Canon 1100D camera on a 30-second exposure from Sunderland in July. I felt extremely excited when I took this image because it really captured the detail and colour vibrancy in the display, it was an absolutely breathtaking display and now I take images whenever I can."

Steve Nichols

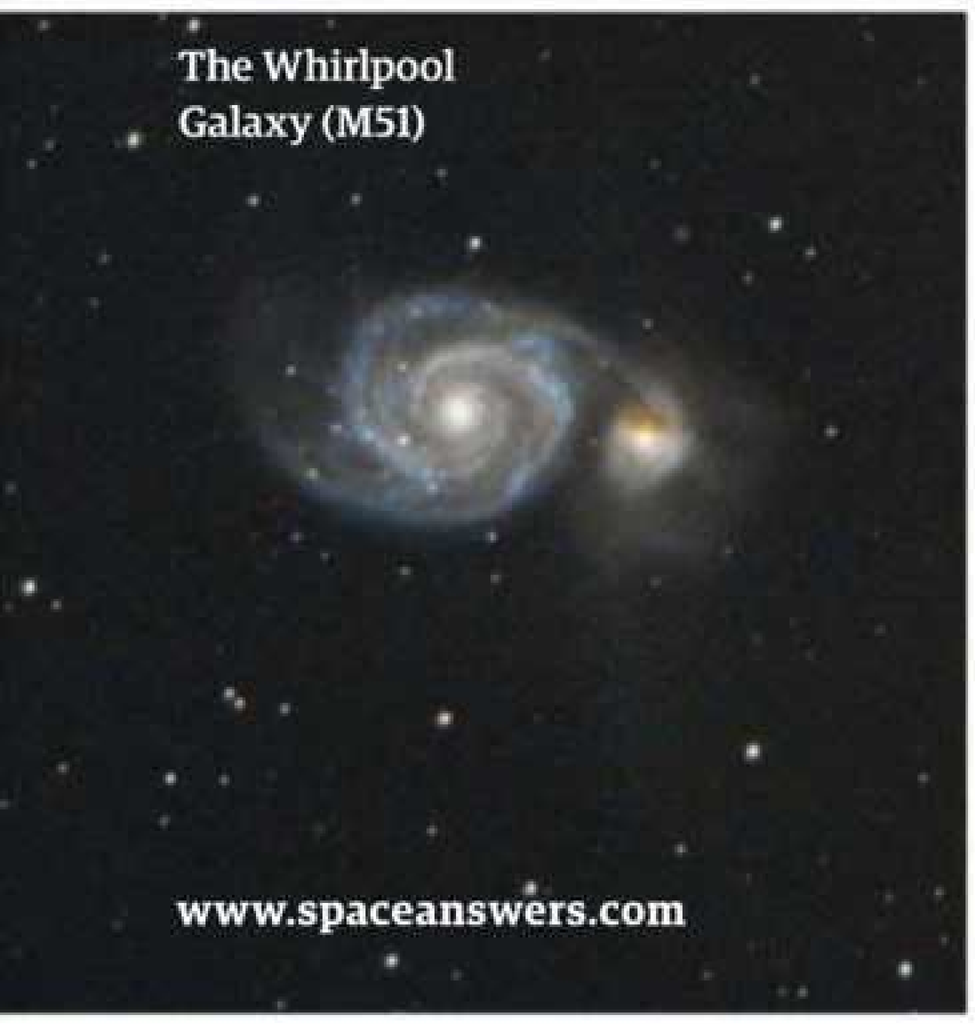
Essex, UK

Telescope: Meade LX90 ACF 12" & Altair Wave Series 115 triplet APO

"I started stargazing about five years ago and my first telescope was a Sky-Watcher 130P. At the time, I had no idea what to do with it or how the mount worked, so I used to just plonk it in the garden and stare at the Moon. Then, in a moment of internet madness, I purchased a Meade LX90 ACF 12" - the first time I saw Saturn through it was fantastic and I stood there for hours. The Meade is not the best scope in the world for imaging deep-sky objects but for planets it's epic. I am now the proud owner of an Altair Wave Series 115 triplet APO. I still consider myself as a newbie to astrophotography and the learning curve is massive but the rewards are worth it."



Bode's Galaxy (M81) and Cigar Galaxy (M82)



The Whirlpool Galaxy (M51)

Send your photos to... @spaceanswers photos@spaceanswers.com

Stargazing stories

Email the story of how you got into astronomy to **photos@spaceanswers.com** for a chance to feature in **All About Space**

Ray Bonner

Location: London, UK
Twitter: @bonner2u
Info: Astronomer for 30 years
Current rig
Telescope: Meade ETX 70AT
Mount: Altazimuth
Other: Canon EOS 400D, 20x80 Zhumell binoculars, 10x50 and 8x30 Binoculars, heavy duty tripod

"I have had an interest in the night sky for most of my life, but living in light-polluted London can make it difficult to observe it. As a youngster I used to spend summer holidays in Donegal in the northwest of Ireland. Here I really began to catch the astronomy bug as the night skies there can be magnificent. I still visit my mother there by the shores of the beautiful Lough Eske, and am still as thrilled now at the sight of my silhouetted hand held up against the Milky Way as I was all those years ago.

"I also had an interest in photography and wrestled with film cameras for years with varying degrees of success, but going digital was the change I needed. London is fine for imaging the Moon and brighter planets (once you take the orange light out with software), but to get those glorious star fields you need to get away from city lights. I have a friend with a farm in Carmarthenshire, so I am often to be seen or heard stumbling about in the dark trying not to knock my tripods over when there is a clear night in either the west of Wales or Donegal.

"I like to image space hardware and a few years ago I was out in the early hours with the camera pointing west because Space Shuttle Discovery (STS-128) was launching from Cape Canaveral, Florida at around 5am our time. Some 20 minutes later, two bright stars shot over the house like flares from a pistol, with a leading bright white star being the orbiter and a following dimmer orange star being the separated orange fuel tank. It was great to be able to see space launches from Walthamstow!" ●

Ray's top three tips

1. Use apps for tracking

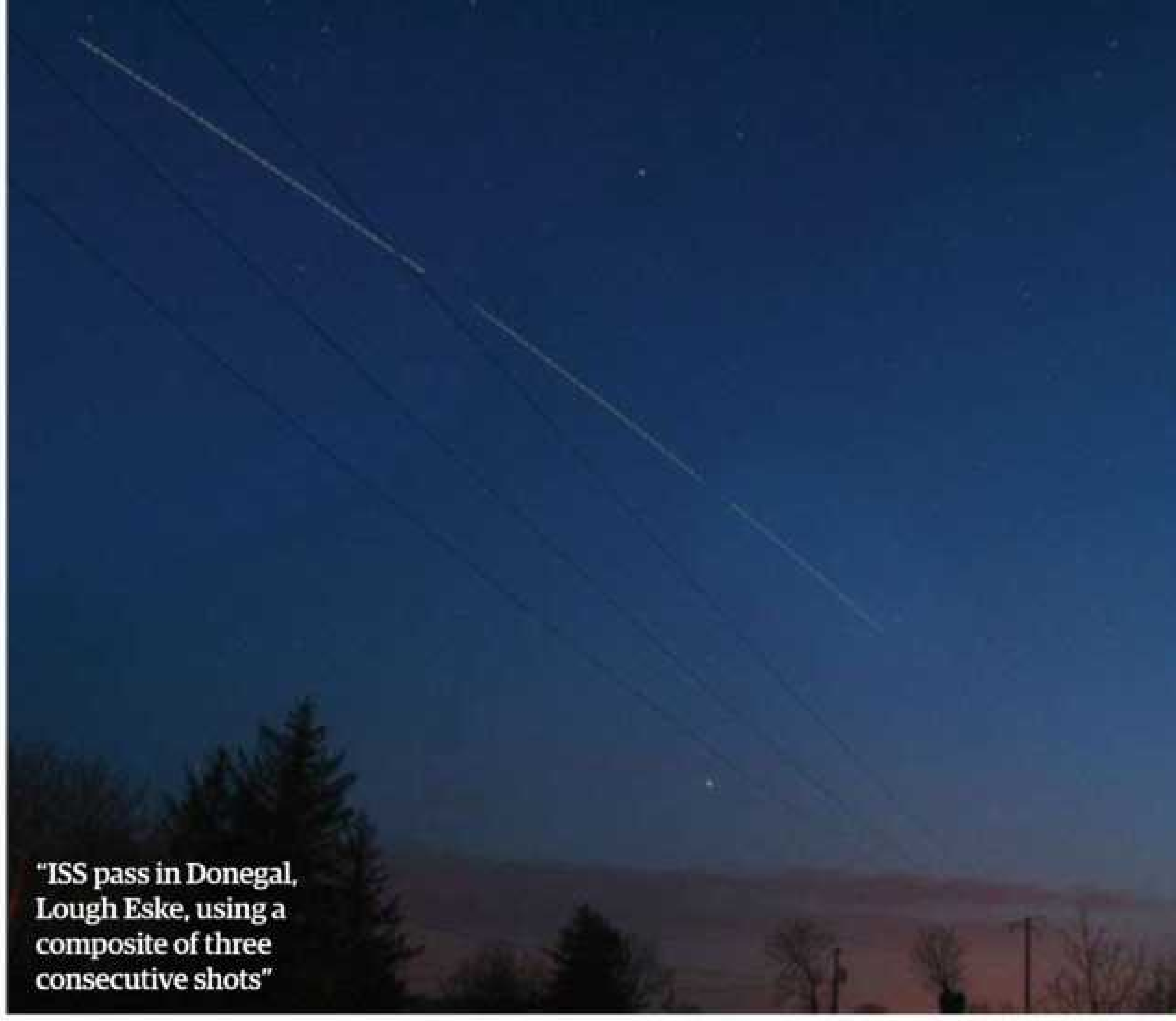
Check satellite passes for your location using smartphone apps - they should give you the time, direction, magnitude and height of a satellite or ISS.

2. Be prepared!

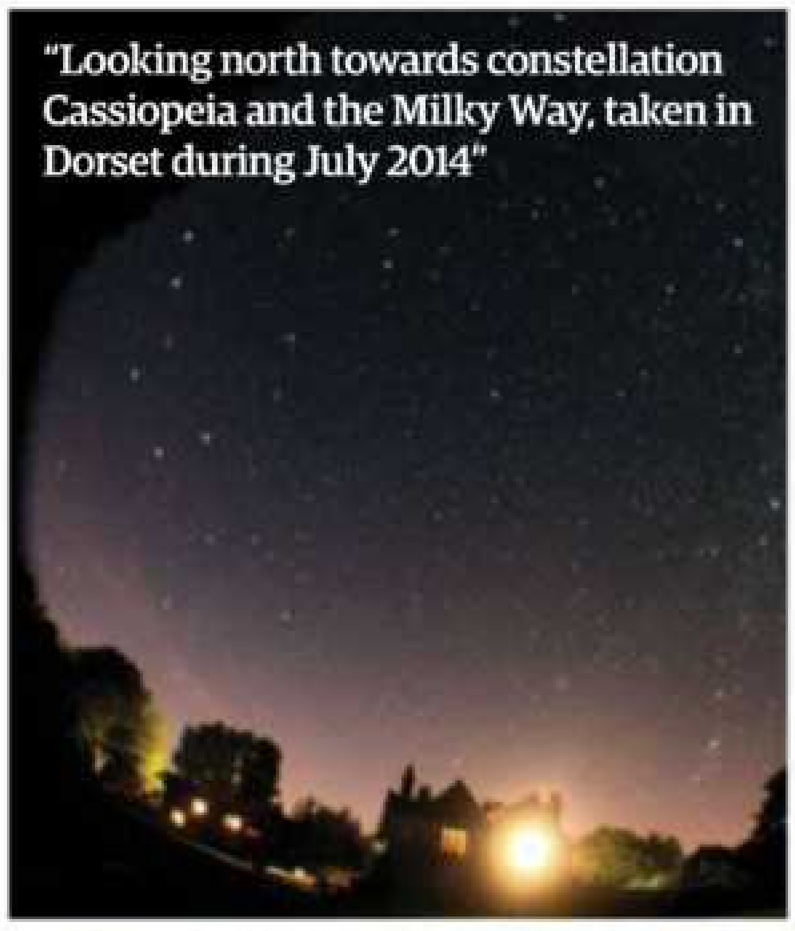
Set up your camera on a tripod ten minutes before the stated pass time, then take practice shots to establish that your line of sight, focus and exposure times are good.

3. Use long exposures

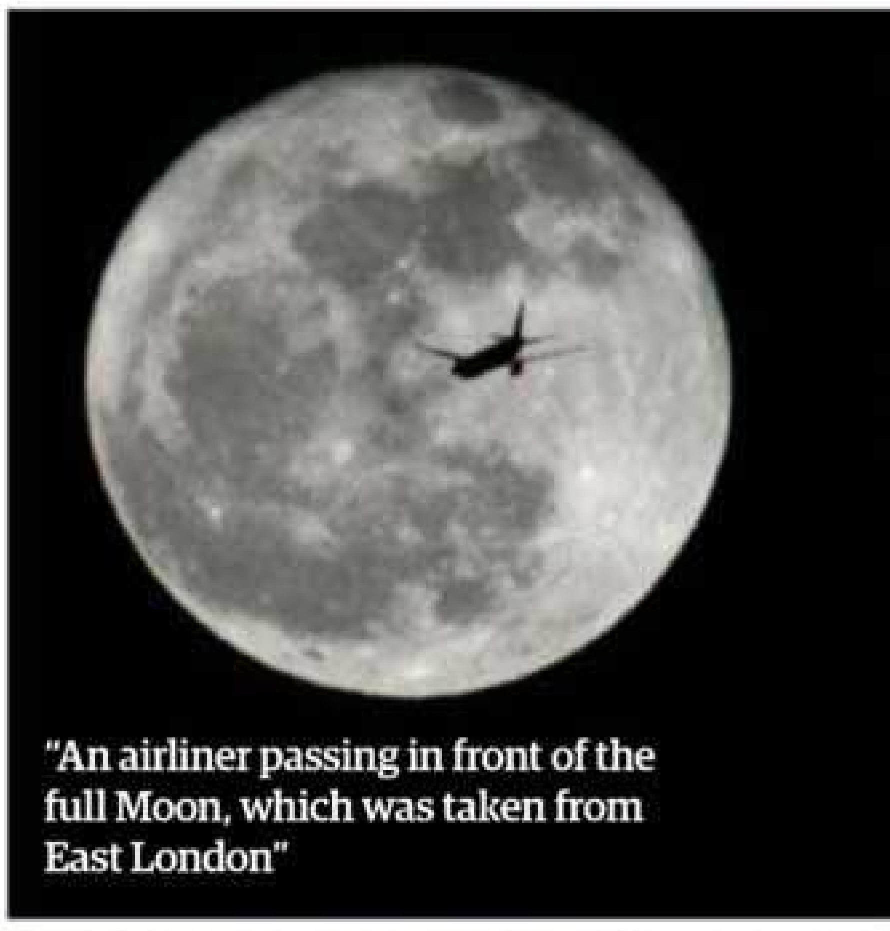
Use a remote control to take successive long exposure shots, this means you can blend them together later on a photo software package.



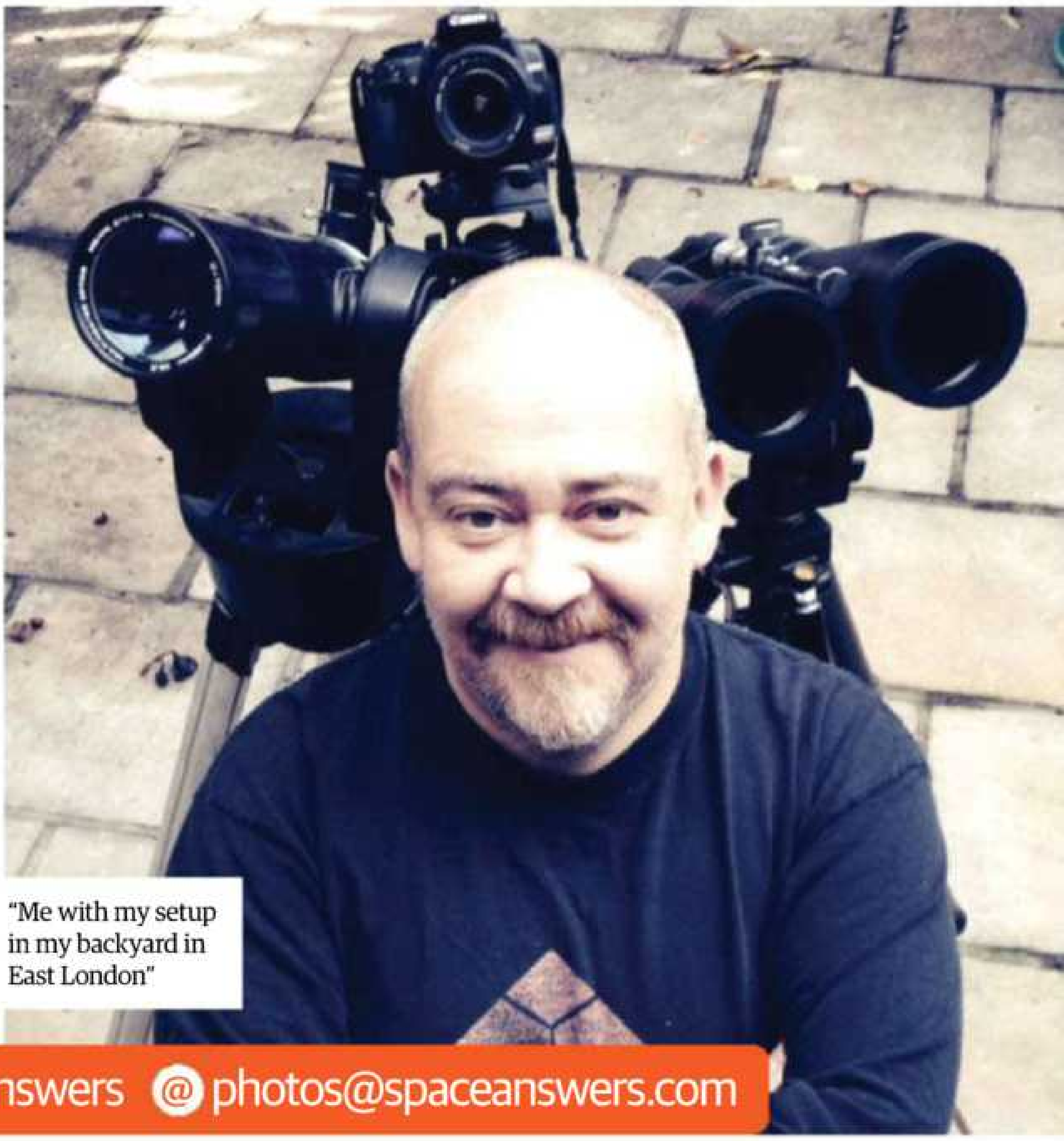
"ISS pass in Donegal, Lough Eske, using a composite of three consecutive shots"



"Looking north towards constellation Cassiopeia and the Milky Way, taken in Dorset during July 2014"



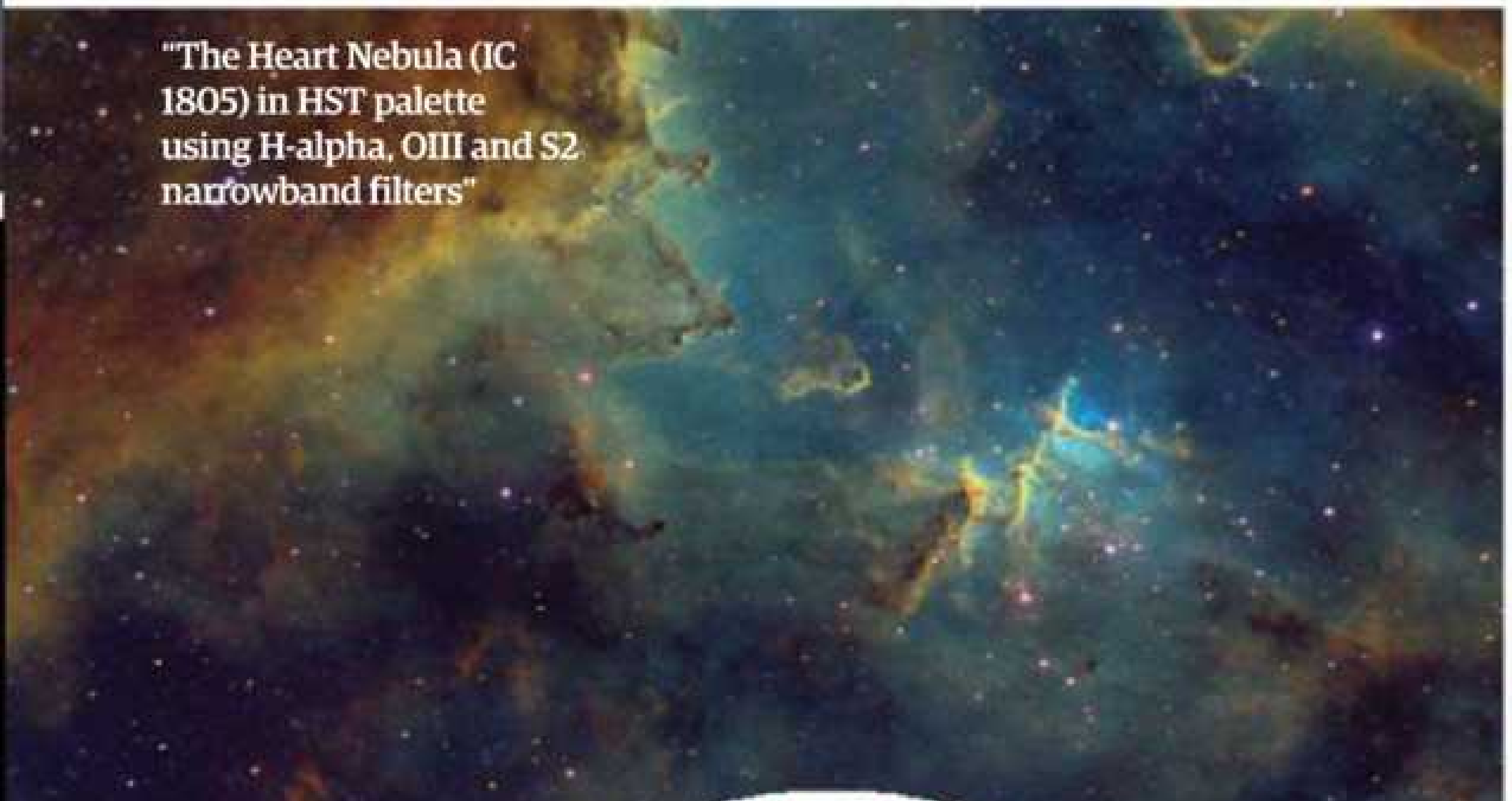
"An airliner passing in front of the full Moon, which was taken from East London"



"Me with my setup in my backyard in East London"

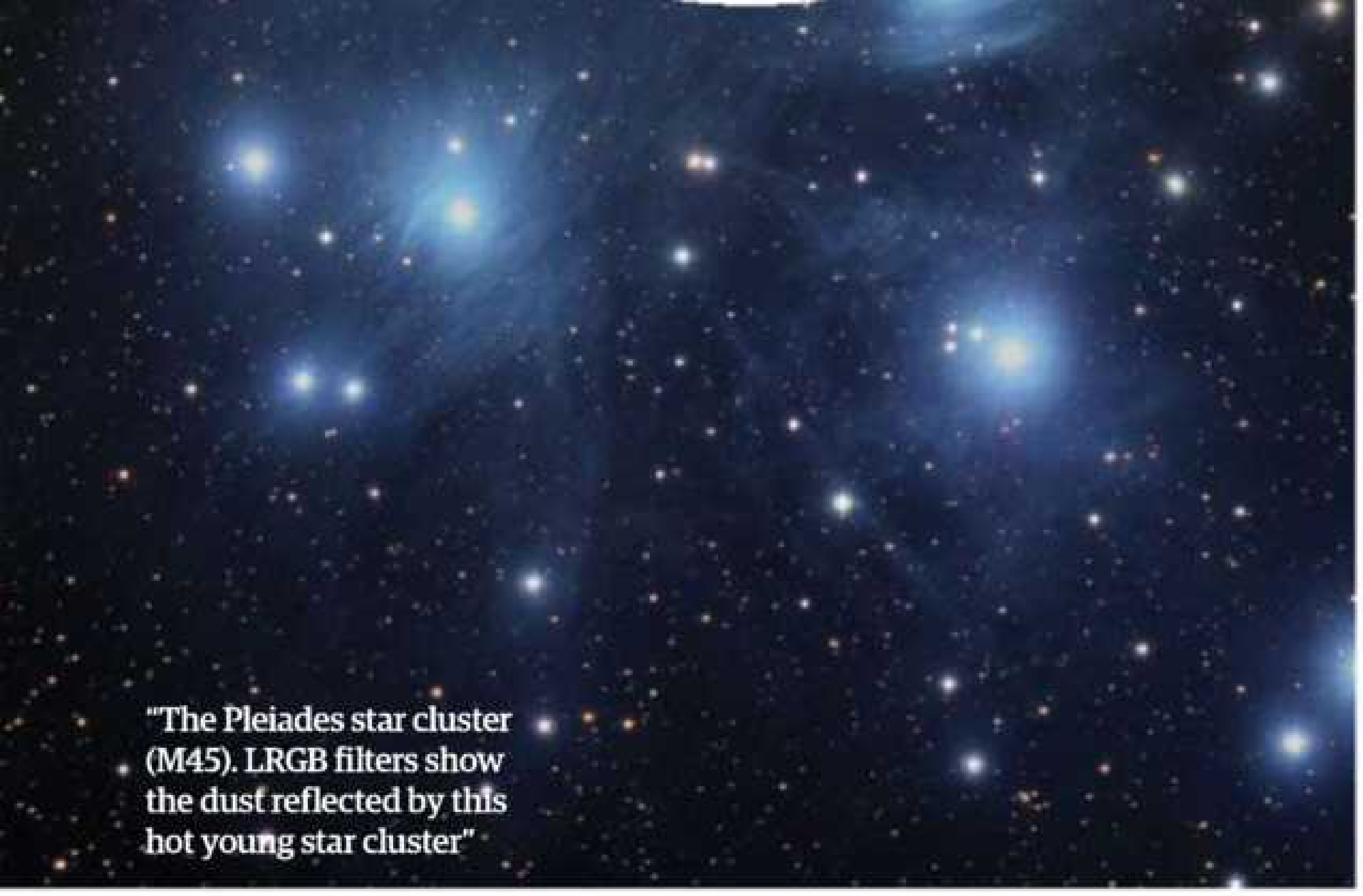
Send your stories and photos to... @spaceanswers photos@spaceanswers.com

"Me with my current setup in my back garden observatory"



"The Heart Nebula (IC 1805) in HST palette using H-alpha, OIII and S2 narrowband filters"

"My previous setup - I had an 8" Ritchey-Chrétien, which is a little heavy for the mount"



"The Pleiades star cluster (M45). LRGB filters show the dust reflected by this hot young star cluster"

Shaun Reynolds

Location: Norfolk, UK
Twitter: @shaunreylec
Info: Astronomer for 4.5 years
Current rig
Telescope: William Optics FLT 98 APO scope
Mount: Sky-Watcher NEQ6
Other: Starlight Xpress SXV 694 Mono Cooled CCD, Sky-Watcher ST 80 telescope

"I became interested in astronomy about five years ago. A friend of mine got himself a scope and mount as he wanted to get into astroimaging and he asked me if I was interested as I like photography. My initial response towards astrophotography was a mild interest but I went to his and we put my Canon 1000D DSLR on his scope and within a couple of 60-second images, I was totally hooked!

"That winter I spent many hours travelling some 20 miles to my friend's house to image. I remember having many very late nights where I returned home at about 4am with some data under my belt ready for processing. Since then I have built my own back garden observatory with a slide-off roof (a shed design) and I image mainly from there.

"The skies are quite good where I live and I'm only two miles from Norwich Astronomical Society, which is based on a very well equipped site. I have been a member of this astronomical society for five years now. Astronomy is the most absorbing and satisfying hobby and I have learnt so much (and I am still learning).

"I have done some outreach at the club, from showing the public some Messier objects to doing my first ever talk last year on astroimaging, which I thoroughly enjoyed despite the first-time nerves!

"A particular highlight for me was getting shortlisted last year for the Astronomy Photographer of the Year by the Royal Observatory Greenwich and having my image published in the book that was produced after the competition. Attending the awards ceremony at Greenwich was a memorable night as I got to meet all of the other photographers." ■

Shaun's top three tips

1. Do plenty of sub-images

More subs equals better signal-to-noise ratio and cleaner images. Not enough time spent on results means nebulae could appear grainy.

2. Get good calibration

Take time to do several darks, biases and flats. If you're spending hours on an image, then spend a bit more time on these to improve smoothness.

3. Don't overprocess

Many small steps rather than one big step is the way forward. A common mistake, but remember, less is more! And save all of your results carefully.

"The shed I image from, which blends in with the surroundings and protects the scope from the wind"

TOP 5 astronomy apps

Never get lost in the sky again, with our favourite tablet and smartphone space apps

01

High-definition navigation, courtesy of SkySafari 4 Pro

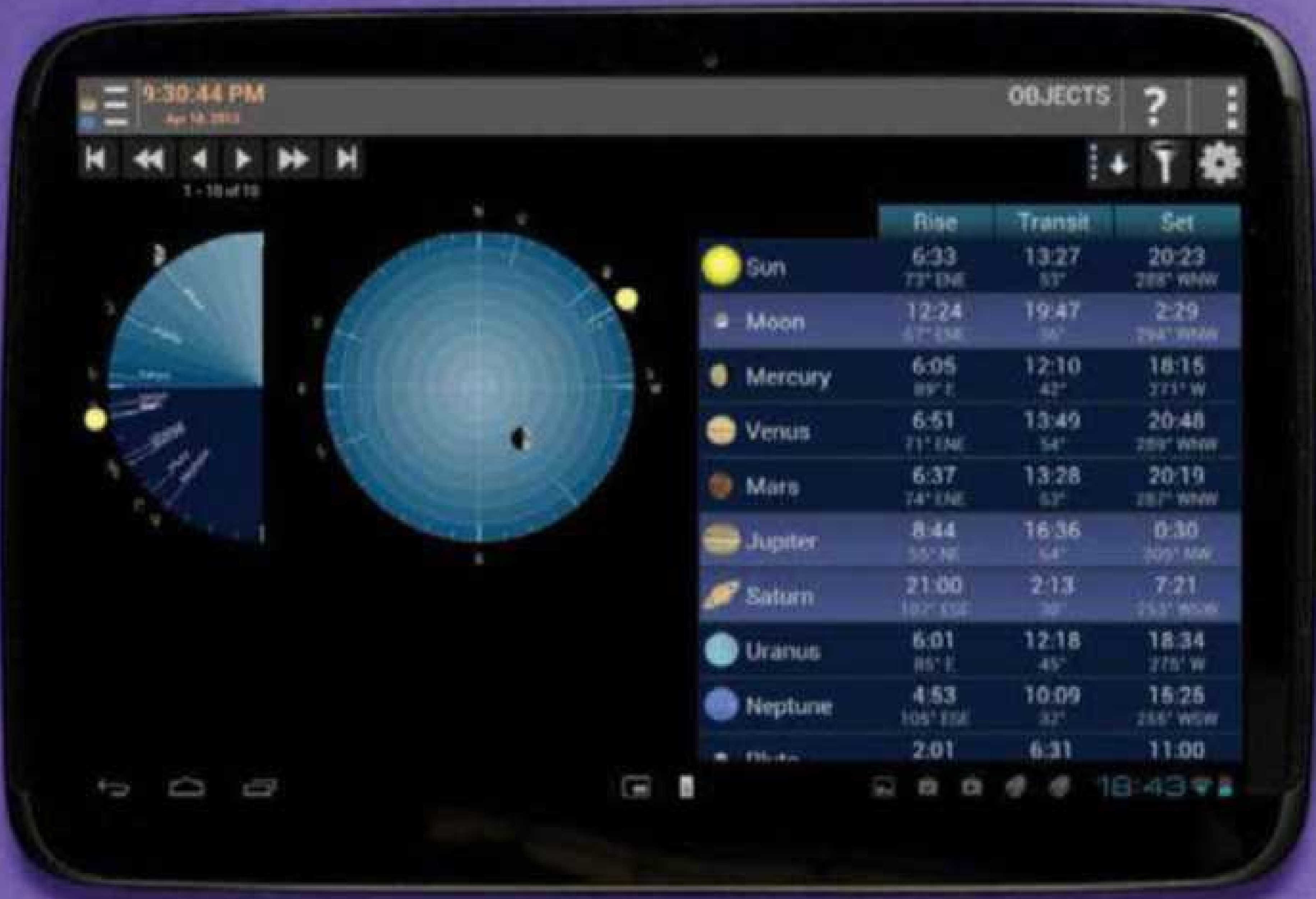
1 Editor's choice
SkySafari 4 Pro

For: iOS/Android

Price: £27.99/£23.43 ($39.99)

The price might be hefty but there's little doubt that SkySafari 4 Pro is one of the leading apps when it comes to looking the part. With a large amount of information about space and features that assist with finding your way around the night sky, SkySafari packs megabytes' worth of celestial objects into its database. You should definitely ensure that you have enough room on your device to not only store this app, but to run it smoothly too. Because it gets the majority of its data from the Hubble Guide Star catalogue with over 15 million stars, as well as other objects such as asteroids and comets in its arsenal, you are truly treated to a high-definition view of the universe.

As an added bonus, the app has a GoTo feature that's capable of controlling your telescope - something that we were highly impressed with. SkySafari is able to identify stars and other objects in the sky at any one time - simply by holding your device up to the heavens, you can easily work out which stars are in the sky and when. We're able to recommend many apps to the stargazer, but the sheer amount of information on offer really sets this app apart from the rest.

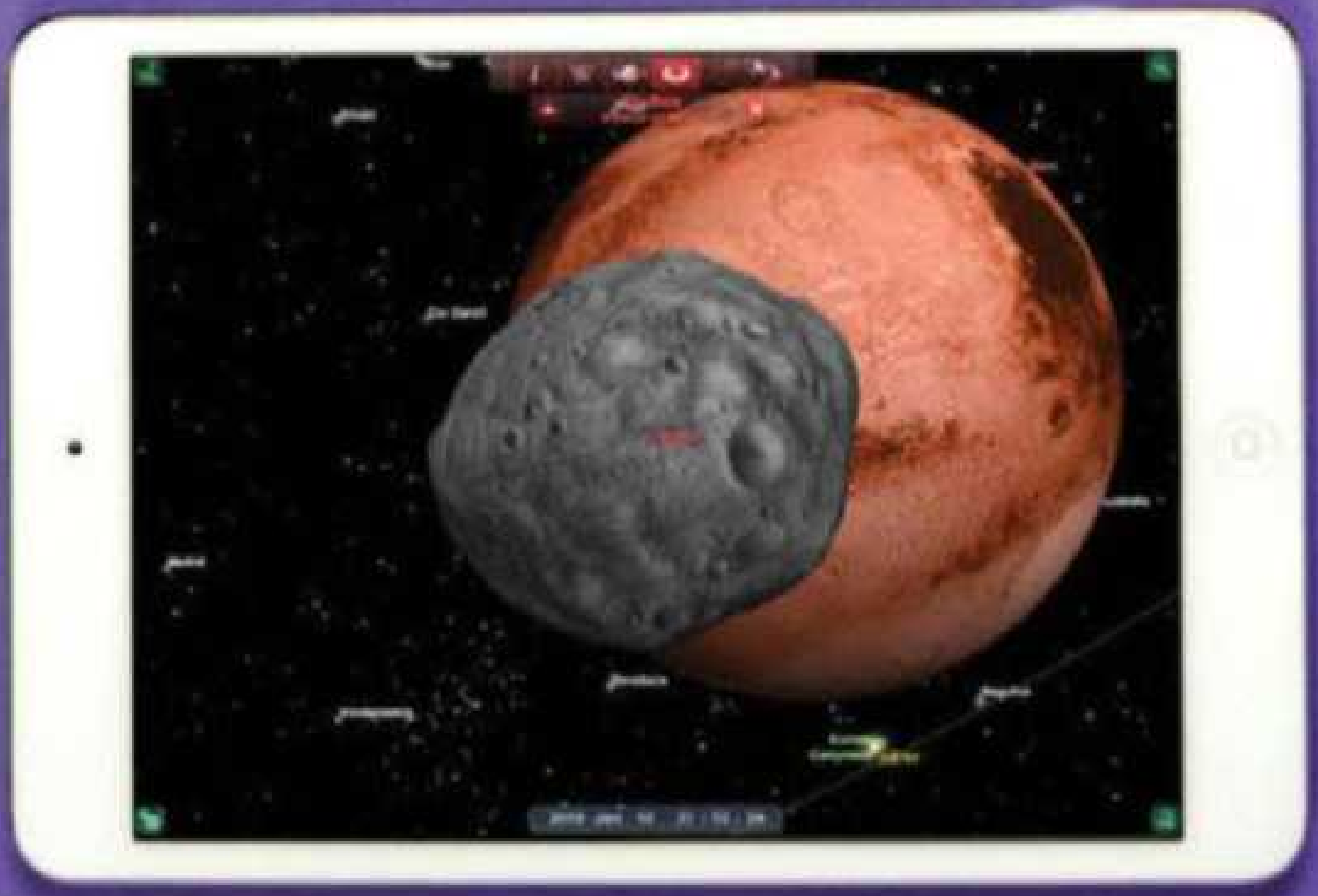


	Rise	Transit	Set
Sun	6:33 73° ENE	13:27 53°	20:23 288° WNW
Moon	12:24 67° ENE	19:47 56°	2:29 294° WNW
Mercury	6:05 89° E	12:10 42°	18:15 271° W
Venus	6:51 71° ENE	13:49 54°	20:48 289° WNW
Mars	6:37 74° ENE	13:28 53°	20:19 287° WNW
Jupiter	8:44 55° NE	16:36 54°	0:30 305° NW
Saturn	21:00 107° ESE	2:13 32°	7:21 253° WSW
Uranus	6:01 85° E	12:18 45°	18:34 275° W
Neptune	4:53 105° ESE	10:09 32°	16:25 255° WSW
	2:01	6:31	11:00

02

03

04



05

Top 5 free stargazing apps

The Night Sky Lite

For: iOS/Android
With community features and viewing spot suggestions.

Planets

For: iOS/Android
Traditional star map and 2D constellation display.

SkyORB

For: iOS/Android
Includes a 3D planet and moon display with stats.

Star Chart

For: iOS/Android
Impressive graphics, above and beyond other free apps.

Distant Suns (Lite)

For: iOS/Android
Easy-to-use tool for learning about the night sky.

2 Best for Android
Mobile Observatory

For: Android
Price: £3.95 ($4.99)

It's great to see that there's something tailored for astronomers who only have access to the Android market here. If you have a compatible device, then we can highly recommend Mobile Observatory, which gives you a top-down view of our Solar System - perfect for those beginning to explore outside our planet's atmosphere.

This app is packed with features and can be daunting for new users but, with a little practice, using it will become second nature. As a guide, Mobile Observatory is able to keep you up to date with what's going on in the cosmos, highlighting key events such as meteor showers and solar eclipses. Similar to many astronomy apps on the market, you're able to point your device at the sky to look and learn about a selection of the stars that are in frame, the constellations they make, as well as the planets that are in the sky at any particular time of the year - all ready for you to follow up with your telescope or binoculars. ■

3 Best for beginners
Star Walk

For: iOS/Android
Price: £1.99/£1.79 ($2.99)

Presenting you with real-time positions for almost every celestial object in the night sky that you could possibly think of, including artificial satellites, Star Walk is a fantastic app for stargazers of all levels of ability - even the novice.

You can pinch and swipe your way around the constellations to your heart's content, and it really is a breeze to find your way around the night sky and locate objects, something that many beginners to astronomy find quite daunting. To use Star Walk, all you have to do is point your device at the night sky and you'll be able to locate and learn about different targets within seconds. The app also packs a generous amount of detail into the motions of the planets across the night sky, as well as the positions of the various constellations that you'll come across on your tour of the cosmos. It's a budget-friendly, highly recommended tool for beginners to practical astronomy! ■

4 Best spaceflight app
NASA App

For: iOS/Android
Price: Free

If you're into all things NASA then you'll love this app, which gives you masses of detailed information on all of the agency's current missions.

What we really liked about the app is that NASA TV is streamed live when there's a press conference. This keeps you up to date with current space affairs - such as updates from the Curiosity rover on Mars - when you're on the go, ensuring that you don't need to be at a computer screen at home to be in on the new announcement. We also admire the great job that the app does in connecting with social networks by allowing you to browse all of the latest tweets for the many NASA accounts currently in action.

Visually, it doesn't look all that impressive, but it's one of a kind and we can't grumble given that it's free. There's a glut of information here for space fans: launch sites, past missions and an International Space Station locator, right at your fingertips. ■

5 Best for armchair astronomy
RedShift

For: iOS
Price: £7.49 ($10.99)

RedShift provides you with a definitive guide to an incredible number of objects dotted around the night sky - all packed into an app with stunning functionality and graphics. Like SkySafari 4 Pro, RedShift doesn't come cheap but given its seamless operation we can see why it's relatively pricey.

Featuring an educational suite that allows users to find objects by their name as well as a browse function, RedShift is excellent for amateur astronomy, as well as for armchair and practical astronomers alike.

It provides you with the option to zoom into distant stars in the night sky, along with a few statistics to learn more about the object you're looking at - some of which are quite mindboggling. RedShift also works well as a reference tool, providing information on more than 100,000 stars, deep sky objects, the biggest asteroids and the most famous comets coming to a Solar System near you. ■

Celestron PowerSeeker 80 AZS

Perfect for beginners, this 'grab and go' refractor offers impressive optics for a budget price

Telescope advice

Cost: £145 ($139.95)
From: David Hinds Ltd
Type: Refractor
Aperture: 3.15"
Focal length: 16"

Best for...

- Beginners
- Low budgets
- Children
- Planetary viewing
- Lunar viewing
- Terrestrial viewing
- Star clusters
- Bright nebulae
- Double stars

Given the precedent that Celestron has set when it comes to the excellent design and optical system of its telescopes, we were very much looking forward to trying the PowerSeeker 80 AZS out. More so because this telescope is a fairly new addition to the market aimed at beginners to the hobby of astronomy.

While many manufacturers are geared more towards the GoTo and complicated 'scopes that require tools as well as nuts and bolts to put them together, it is very refreshing to discover that we were able to put this refractor telescope together in less than ten minutes. What's more, we didn't really need to use the instructions - which are very comprehensive we might add - since it was so intuitive. There is no need for Allen keys or screwdrivers and it's easy to fit the 16" tube to the altazimuth mount and tripod. Extra fixtures, such as the finderscope are also a breeze to attach. With a sturdy, collapsible mount and a very lightweight design, we could recommend this refractor to a family and to those who are looking for a 'grab and go' 'scope, which can easily be packed up and put in the back of the car.

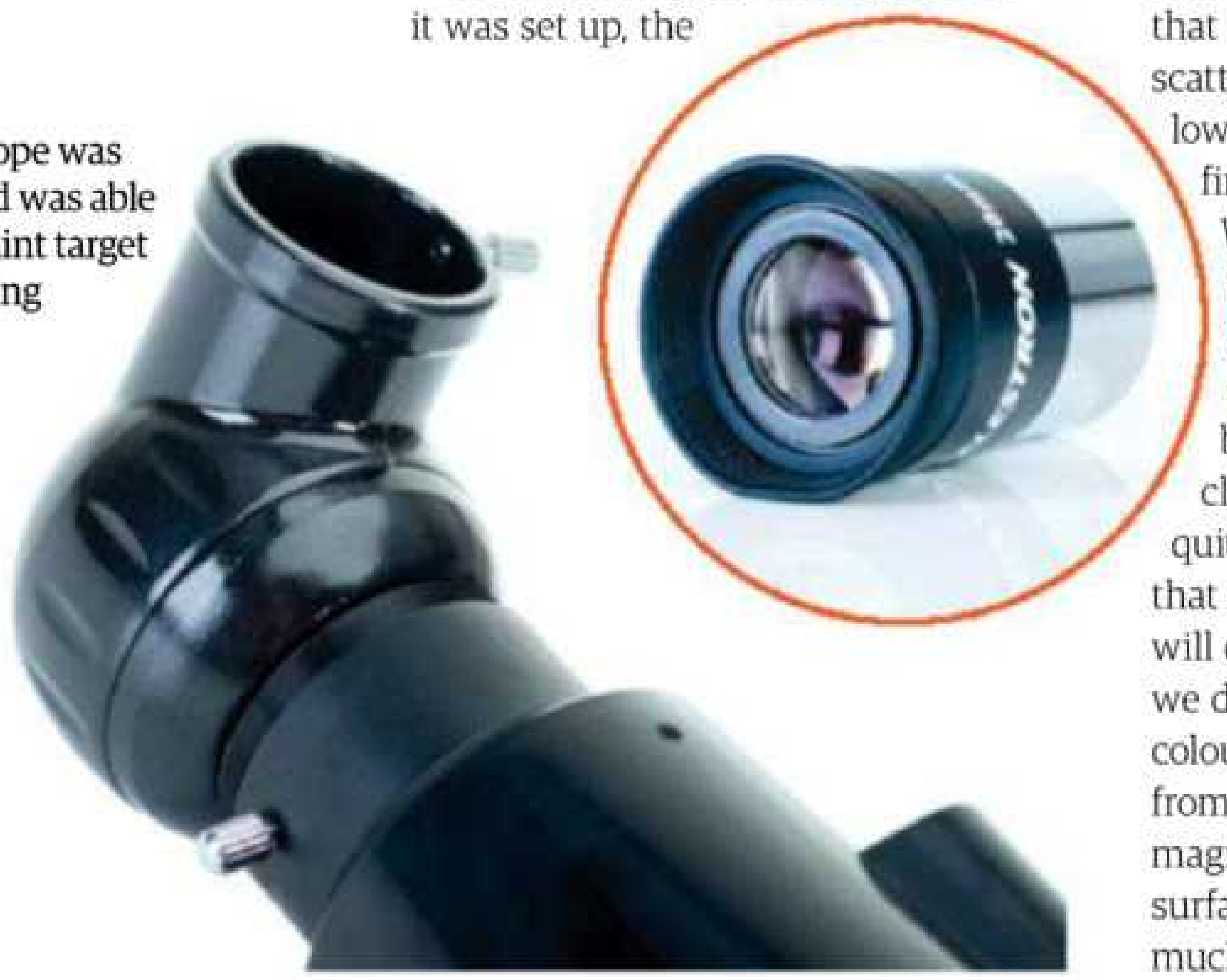
On inspecting the telescope once it was set up, the build is fair for the price. As you would expect with many budget telescopes, the PowerSeeker's focusers are made of plastic, as is its 90-degree diagonal. While this isn't a massive drawback, there are budget telescopes of similar price with higher quality focusers. On its tripod, this refractor is one that you would need to take extra care with, since it is not as robust as other budget telescopes we have reviewed in All About Space. However, the altitude-locking bar, used for keeping everything in place, did a sound job.

As with previous Celestron models that we've taken for a spin under the night sky, we had high hopes for the PowerSeeker's optics. Given the refractor's f5 focal ratio, which offers a wide field of view, we were looking forward to turning the telescope tube to a variety of different targets within reach of its optical limits - bearing in mind its highest useful magnification of 189x and lower end of 11x. With only one supplied Plössl eyepiece, we were limited to a magnification of just 20x, however.

Keeping the price of this telescope in mind, we thought that the PowerSeeker's optics were very good for the money. Initially, we did worry that with an erecting image diagonal, that there would be a degree of scattering. Yet, given the telescope's low power and rich-field, we didn't find this to be a particular problem. With the last quarter of the Moon in the sky, we took the opportunity to view its craters, which were beautifully picked out by the lunar terminator. As far as clarity goes, this refractor provided quite sharp, bright and clear views that many beginners to astronomy will enjoy and will be proud of. Sadly, we did notice a degree of pesky colour-fringing, but this didn't detract from the views through it. The low magnification meant that the lunar surface didn't fill the field of view too much - and means that beginners won't get 'lost' looking at the Moon's surface. The 5x24 finderscope did a satisfactory job in assisting with manually moving across the Moon's surface, to provide clearer views. We did find that it was quite small though - something that might put some observers off. However, we thought that the finderscope's size gave a true indication of what the PowerSeeker could achieve and it was quite capable of picking out faint stars that were ideal for star-hopping.

Swinging the telescope up and down and left to right, the altazimuth mount was easy to move, however, we did hold the tripod to add a bit of extra stability - just in case - as there was a slight degree of shaking.

Given the telescope's wide field of view, it's capable of picking out star



The 5x24 finderscope was used with ease and was able to pick out a few faint target stars for star-hopping

The multicoated lenses provided clear and crisp sights, however, there was some slight colour-fringing

"Offers sharp, bright and clear views that many beginners to astronomy will enjoy"

clusters and split double stars with ease, akin to a pair of binoculars. We quickly and easily split double stars Alcor and Mizar in Ursa Major and got down to observing star clusters, such as the Pleiades, as well as the Orion Nebula. Clear and crisp sights thanks to the multicoated lenses were had and we felt that this is something that the PowerSeeker excelled at.

Overall, the telescope is a good choice for beginners. The basic standard of extras included made us feel that it would benefit from some additional eyepieces, to make the most of the upper limits of magnification. Not only that, but a much improved diagonal would benefit the telescope greatly. All in all, though, a very good telescope given the price, and one that'll last for some time. ●

A plastic focuser, the lower quality of which wasn't entirely unexpected given the price of the telescope

The PowerSeeker 80 AZS employs an altazimuth mount

8x25 binoculars

Suitable for basic lunar observing, we put these light 8x25 binoculars head-to-head to see which pair gives more bang for the buck

Minox BV 8x25 BRW

Cost: £105.60 ($169)
From: www.365astronomy.com

Compared to the Barr and Stroud Saharas, these binoculars have a less rugged design, but are similarly comfortable during use and are nice and light, too.

When it came to using these binoculars for lunar viewing, we felt that the lens quality was better than that of the Barr and Stroud binoculars. They produced clear, bright views surprisingly well for the 25mm objective and the image stays in focus for a very good proportion of field of view. The focus was very smooth, extremely quick and precise - and really proved to be one of several things we loved about these binoculars. They had an excellent depth of field, too.

Since the Minox work well under low-light conditions, we got better views of star fields than with the Barr and Strouds. However, for individuals who want binoculars solely for stargazing, you're much better off getting a more powerful pair. For basic views of the Moon and wildlife though, the Minox get our vote.

Barr and Stroud Sahara 8x25

Cost: £58 ($137)
From: www.365astronomy.com

On first impressions, these binoculars certainly looked as if they would be up to the task. And we weren't disappointed either - especially because their price should sit comfortably for both those on a tighter budget and anyone interested in nature watching and the occasional view of the Moon.

They are quite chunky, but fit in the hands well. While they were light enough to wield comfortably, they were also reassuringly heavy, which illustrates the quality of their build and allowed for steady views of the lunar surface. An added bonus was the waterproof design, making these binoculars perfect for damp conditions.

While we got clear views and well-defined features on the Moon's surface, we found that the eye relief wasn't the best. To get around this, you can hold the eye-cups slightly away from the eye, but we found this to be tiring on the arms, especially when observing for long periods of time.

For astronomy, we recommend going for a decent pair of 10x50 binoculars, since the exit pupils limit you when it comes to truly scanning the night sky. They did, however, do a decent enough job for lunar observations.

Astronomy kit reviews

Must-have products for budding and experienced astronomers alike

1 Telescope
Visionary First View 76mm

Cost: £49.99 (approx. $80)
From: www.opticalhardware.co.uk

As far as basic 'grab and go' telescopes go, this 'scope is great value for money, particularly as it comes with eyepieces included. What we like most about this starter 'scope is that if you're just looking to pique an interest in astronomy you don't have to spend a massive amount to do so. What's more, there's no 'setting up' involved.

Optically, views were impressively clear and certainly made an impression when combining the 'scope's optical system with the 12.5mm and 4mm eyepieces. A nice touch was that filters can also be attached to these eyepieces, however, this instrument is best for large, obvious night sky targets such as the Moon. As expected, we got basic views of Jupiter as a star-like point and could just about make out its four largest moons, but got pleasing sights of the lunar craters and lunar mare.

2 Diagonal
Ostara 2" dielectric 90-degree diagonal

Cost: £99 (approx $160)
From: www.opticalhardware.co.uk

A huge plus of this diagonal is its stunning build quality and beautiful finish – but does it work as well as it looks, and is it value for money?

When we secured the Ostara 2" diagonal to our in-house refractor, we were immediately able to use the instrument much more comfortably. Not only that, the 99 per cent reflectivity certainly assisted when we turned our telescope to a variety of targets. It meant that our telescope was able to achieve excellent brightness and stunning contrast when viewing the Moon, for example.

Slotting eyepieces into the diagonal, we found there was a degree of versatility when it came to fixtures with both the 1.25" and 2" openings. We only had the opportunity to try out the 1.25" adapter, but we were pleased to discover that the eyepieces slotted in securely.

3 Planisphere
Collins Planisphere (Royal Observatory Greenwich)

Cost: £9.99 (approx $16)
From: www.amazon.co.uk

The Royal Observatory Greenwich has teamed up with Collins to make finding your way around the night sky easier. Using a planisphere is quite comprehensive, but this one comes with detailed instructions.

Planispheres can be made of cheap card, so we were happy to find this one is made of plastic, which promises to last for many observing sessions.

Taking on an observing trip, we were able to set the 'wheel' with ease to pinpoint a real-time view of the constellations and the objects visible that night. Star magnitudes and red supergiants were represented well on the chart as well as several of the more obvious galaxies in the night sky at any one time. The planisphere managed well under a red torch, making it a good choice for beginners in astronomy.

4 Book
Philip's Deep Sky Observer's Guide

Cost: £9.99 (approx $16)
From: www.amazon.co.uk

Using this guide during our observing sessions, it quickly became apparent how beginner-friendly it is. Written by astronomer Neil Bone, it focuses on the brighter Messier objects and avoids bogging the reader down with targets that are too faint to observe.

Bone also provides step-by-step instructions and maps on how to find these objects by star-hopping, and we found each target with ease.

It opens with a chapter covering the basic techniques and kit that you need to find deep sky objects, before galaxies, star clusters, nebulae and the like are each given a separate chapter. This allowed us to flick to targets quickly for reference.

Providing details on both famous and not-so-familiar deep sky objects, this guide was a great reference as well as a teaching tool. An excellent guide that we highly recommend!

WIN A BEGINNER'S TELESCOPE BUNDLE

We've got the perfect giveaway for anyone just breaking into astronomy

As part of our beginner's guide to astronomy, this issue we're giving away an entire telescope bundle worth over £300, courtesy of Optical Hardware (www.opticalhardware.co.uk).

A new arrival on the astronomy market, the brand-new Visionary STARLA 80 refractor telescope, complete with 10mm and 25mm eyepieces, will truly kickstart your tour of the night sky. Thrown into this competition are a pair of Helios Nature Sport 10x50 wide-angle binoculars, set to provide you with clear and quick hassle-free views of some of your favourite astronomical targets. And that's not all we're giving away – we've made finding your way around the night sky a touch easier with a Philip's Planisphere and Sir Patrick Moore's *Guide To Stars And Planets*, as well as a handy stargazer's notebook to keep a record of all of your observations.

Visionary
Collins
PLANISPHERE
FOR USE IN THE UK AND IRELAND, NORTHERN EUROPE AND CANADA
IDENTIFY THE CONSTELLATIONS AND STARS EVERY DAY OF THE YEAR
PHILIP'S Guide to
STARS & PLANETS
SIR PATRICK MOORE

WORTH OVER £300

To enter, all you need to do is answer this question:

Which colour of light is best for keeping your night vision?

A: Red

B: White

C: Yellow

Enter online at: **spaceanswers.com/competitions** Visit the website for full terms and conditions

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Oberth (front) along with officials of the US Army Ballistic Missile Agency in 1956

Hermann Oberth

One of the lesser-known founders of modern rocketry and astronautics

While America's Robert Goddard is often credited as being the 'father of rocketry', he was by no means the only influential figure in propelling astronauts into space. Hermann Julius Oberth was of the same generation as Goddard, born in what would become modern-day Romania, in 1894. He developed a passion for science and science fiction at an early age, obsessing over the likes of Jules Verne's *Around The Moon* and *From The Earth To The Moon*.

Although he was already toying with rocket concepts and rocket science by his early teens, he was too far ahead of his time and he lacked the resources to pursue a career in this area. Instead, he went to study medicine in Germany in 1912, but that too was scuppered by the outbreak of World War I. Oberth was enlisted into the Imperial German Army and sent to fight the Russians on the Eastern Front, before being moved to work in a military hospital. It was here he found the time to return to his experiments in rocketry, even demonstrating a liquid propellant rocket for the Prussian minister of war.

Following the end of World War I, Oberth returned to Germany to study physics. His work in the relatively unknown area of rocketry wasn't taken seriously though, and it wasn't until 1923 that he finally obtained his doctorate in physics.

By the end of the Twenties, Oberth's work had begun to pick up some traction. He fired his first liquid fuel rocket motor in 1929, assisted by none other than an 18-year-old Wernher von Braun, a controversial but nevertheless crucial figure in the development of the rocket programme.

Like Von Braun, he was caught up in the Nazi regime's Army Research Center in Peenemünde, where he helped develop the V-2 rocket, among other top-secret projects. Peenemünde itself is generally regarded as the birthplace of modern rocketry.

After the war, Oberth focused more generally on space and astronomy, writing a book on spacecraft, space stations and spacesuits. A stretch of the imagination and a subject for science fiction in the Fifties when it was published, but Oberth was later to prove that, once again, he was a thinker ahead of his time.

Like a number of prominent German rocket scientists that were formerly under the employ of the Nazis, Oberth moved to the US where he found himself working for none other than his former assistant, Wernher von Braun. He contributed ideas to the next decade of space technology and also became a technical consultant on the Atlas rocket programme: this was the rocket that launched the first four US astronauts into orbit and has gone on to be involved in around 600 launches across its five basic models.

During the peak of his career in the Fifties, Oberth openly supported the idea of an extraterrestrial origin of unidentified flying objects that had been reported around the globe, stating, "flying saucers are real and are spaceships from another solar system... possibly are manned by intelligent observers."

Oberth retired in 1962 and died in 1989. He has a lunar crater named in his honour as well as an astronautic principle: the Oberth effect. ●

All About Space

Imagine Publishing Ltd
Richmond House, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ
☎ +44 (0) 1202 586200
Web: www.imagine-publishing.co.uk
www.greatdigitalmags.com
www.spaceanswers.com

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Cover images
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Photography
NASA, ESA, ESO, Harvard CFA, C. Malin, Tobias Roetsch, Adrian Mann, shojinko, Tryfon Kar, Skala, National Ignition Facility, Science Photo Library, Alamy, DK Images, Corbis, Nicolle Fuller, SKA, Mike Peel; Jodrell Bank Centre for Astrophysics, University of Manchester, L. Calçada, NOAA, GSFC, Suomi NPP, VIIRS, Norman Kuring, Roscosmos, AURA, STSc, J. Emerson, VISTA, All copyrights and trademarks are recognised and respected.

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Subscriptions
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Email: allaboutspace@servicehelpline.co.uk
13 issue subscription (UK) – £41
13 issue subscription (Europe) – £50
13 issue subscription (USA) – £50
13 issue subscription (ROW) – £60

Circulation
Head of Circulation Darren Pearce
☎ 01202 586200

Production
Production Director Jane Hawkins
☎ 01202 586200

Founders
Group Managing Director Damian Butt
Group Finance and Commercial Director Steven Boyd

Printing & Distribution
Wyndeham Peterborough, Storey's Bar Rd, Peterborough Cambridgeshire, PE1 5YS
Distributed in the Rest of the World by: Marketforce, Blue Fin Building, 110 Southwark Street, London, SE1 0SU
☎ 0203 148 3300
Distributed in Australia by: Network Services (a division of Bauer Media Group), Level 21 Civic Tower, 66-68 Goulburn Street, Sydney, NSW 2000
☎ + 61 2 8667 5288
Distributed in the Rest of the World by: Marketforce, Blue Fin Building, 110 Southwark Street, London, SE1 0SU
☎ 0203 148 8105

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ISSN 2050-0548

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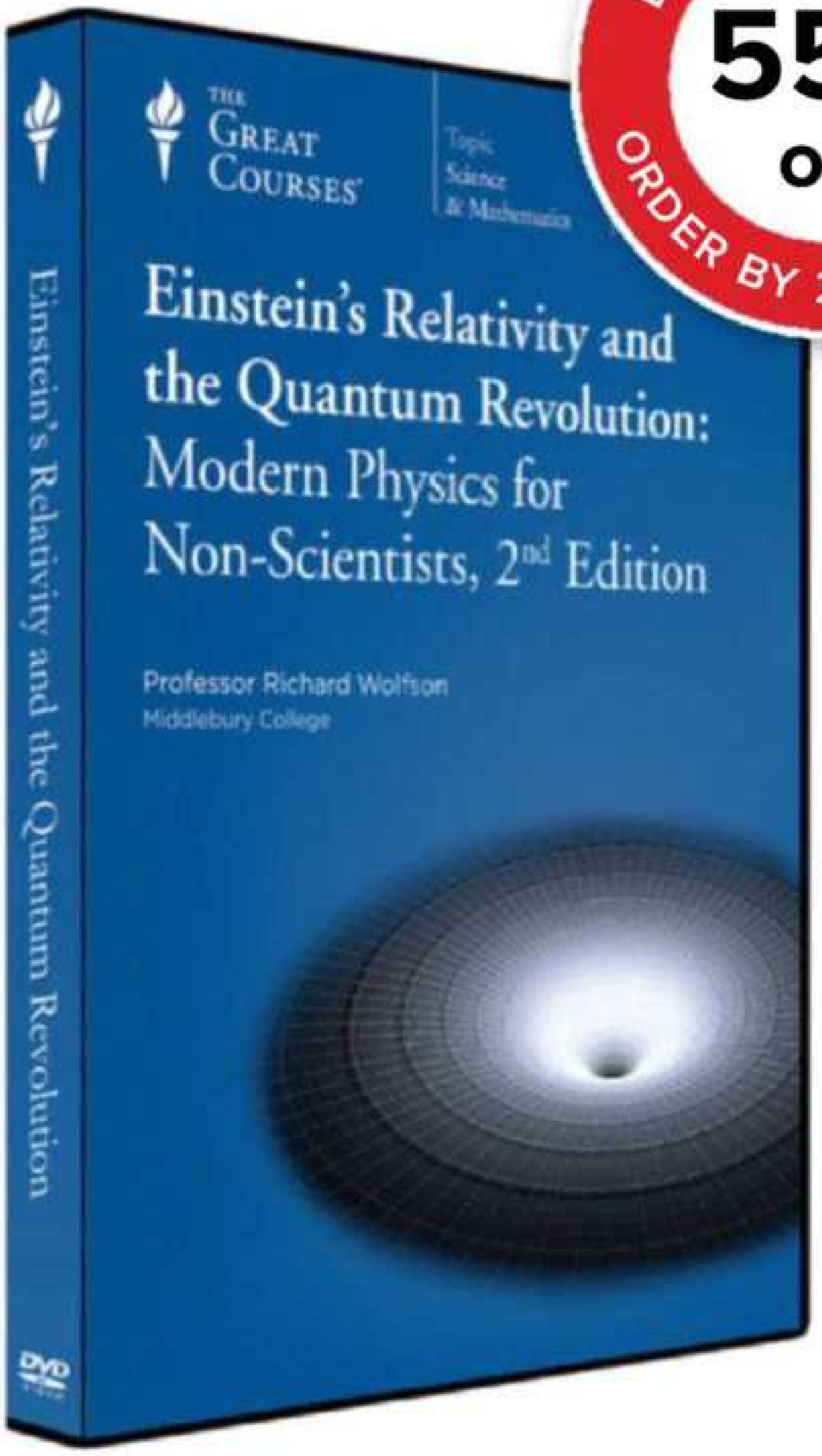
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Sky at Night MAGAZINE
REVIEWED IN
ISSUE 112 SEPTEMBER 2014
★★★★★

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